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RASPBERRY NUTRITION

I. SEASONAL VARIATION OF PLANT NUTRIENTS IN RASPBERRY PLANTINGS UNDER DIFFERENT CULTURAL TREATMENTS

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INTRODUCTION

An investigation into the causes of raspberry failures and low yields in certain sections of the Lower Mainland of British Columbia soon disclosed the fact that the problem of soil deficiencies in available nutrients was of paramount importance. Having no previous work of this nature for a basis of comparisons it was decided to make a careful study of the seasonal variations of plant nutrients under different cultural treatments.

PLAN OF EXPERIMENT AND PLOT TREATMENT

Plot Treatment.—In the spring of 1930 five blocks of Cuthbert Raspberries were planted at the Dominion Experimental Farm, Agassiz. In these blocks twenty-eight uniformly distributed plots were selected. Each plot consisted of two adjacent 50-foot rows, each containing twenty plants with buffer rows on each side of the plot. Rows were spaced 7 feet 6 inches apart. The area was clean cultivated in 1930. In 1931 the various treatments were commenced, including cover cropping with clover, rye, and vetch, and fertilizing with barnyard manure, complete artificial fertilizer and sodium nitrate. These treatments, together with check plots receiving no treatment, were replicated once in each of the five blocks and allocated so that the maximum distribution was obtained over the whole area.

Rye, vetch, and clover were seeded at 112, 112, and 20 lbs. per acre respectively on May 9. Well-rotted barnyard manure was applied at the rate of 13 tons per acre on March 28. Complete fertilizer (5-10-6) was applied at the rate of 750 lbs. per acre on April 3. Nitrogen fertilized plots were treated with an application of nitrogen equivalent to that given in the complete fertilizer on May 9. Plots which were not cover cropped were cultivated during the growing season to keep down weeds. The area was plowed as a whole on April 4, disced April 20, hoed May 13, cultivated May 20, disced July 21, hoed August 10, disced August 13. Rye was disced down July 21, clover and vetch were turned under August 13.

Sampling.—Soil samples from each plot were taken during 1931 in the months of March, May, July, September, November, and also again in March, 1932. All samples were air dried.

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These samples were brought to the University of British Columbia and analysed in the Horticultural (Plant Nutrition) laboratories. Thus throughout the year the effect on the available food supply of the various cover crops and manures was obtained.

SOIL ANALYSIS.—The soil used was a fine silt carrying with it a considerable amount of clay. An analysis of this soil by Shutt (*9*) in 1893 was as follows:—

Water	3.24%	Magnesia	1.45%
Organic volatile matter	6.96%	Potash	0.33%
Clay and sand	75.14%	Soda	0.17%
Oxide of iron and alumina	10.83%	Phosphoric acid	0.25%
Lime	0.94%	Carbonic acid	0.46%
		Nitrogen	0.148%

For the present experiment the method used to obtain soil samples was that outlined by Russell (*8*). On each sampling date moisture determinations were made and are indicated below:—

Mar. 14	29.6%	July 23	22.4%	Nov. 24	27.5%
May 20	25.1%	Sept. 23	24.4%	Mar. 13	27.5%

Available nutrients were determined in the soil solution.

Method.—The method of obtaining the soil solution was one of displacement, outlined by Burd and Martin (*2*, *3*), in which 2 kilos of soil are packed into brass tubes 17 inches long and 3 inches in diameter: at the bottom is a brass screen covered with filter paper, below which a tube leads out; the top is fitted with a screw cap and tube so that air pressure can be applied. 400 cc. of water are poured on the soil and air pressure increased usually up to 100 lbs. till the liquid runs through.

The solution is collected in 10 cc. fractions: the first lot are uniform in composition as shown by their electrical conductivity and are assumed on good experimental grounds to represent the true soil solution. This method according to Russell is the most convenient of the various methods described for displacing the soil solution (*8*). A battery of 6 extraction tubes was used.

It is of interest to note here that the average time required to displace the soil solution was about 3 hours, and that all samples taken in March, 1931, and March, 1932, took 1½ to 2 hours longer to be displaced than samples taken at any other time, while samples taken in July were without exception the fastest. All displacements were made at a moisture content of 27%.

The determinations made on the soil solution were: Electrical conductivity, pH, and the following ions: nitrates (NO_3), potassium (K), phosphates (PO_4), magnesium (Mg), chlorine (Cl), bicarbonates (HCO_3), calcium (Ca), and sulphates (SO_4). (*1,4,7,5*).

Conductivities were read as ohms resistance of the solution at 20° C. pH was determined with a quin hydrone electrode and checked colorimetrically.

PRESENTATION OF DATA

Nitrates

TABLE 1.—NITRATES IN SOIL SOLUTION IN PARTS PER MILLION

Soil treatment	Dates samples taken						Total average for treatment
	Mar. 14, 1931	May 20, 1931	July 23, 1931	Sept. 23, 1931	Nov. 24, 1931	Mar. 13, 1932	
Rye	24	300	62	155	89	25	109.3
Clover	23	269	23	272	105	33	121.1
Vetch	26	297	117	202	133	25	133.3
Fertilizer	33	346	151	295	172	18	169.2
Manure	40	557	238	346	216	19	236.0
Nitrogen	44	415	254	295	177	17	200.0
Check	51	399	221	399	199	30	216.5
Mean average	34.4	369	152.3	266.3	156	23.9	168

Nitrates show (in Table 1) a very well defined seasonal trend. In March they are very low, in May they are high; in July they fall to a low figure and in September they are high again. In November they fall off and continue falling until a very low concentration is reached the following March.

While there is some variation in the initial March 14th determinations before treatments, it is obvious that the very low July concentration of nitrates under rye, clover and vetch is due to the feeding of these crops. Clover appears to reduce the nitrates the most during the summer period, but after plowing the crops under, rye seems to be the least advantageous.

Fertilizer, manure and nitrogen applications appeared to maintain to some extent a higher concentration of nitrates than would have otherwise prevailed during the low July period. The high figures shown in the check plot are surprising, but it is to be noted that in the initial March analysis they are high.

Phosphates

TABLE 2.—PHOSPHATES IN SOIL SOLUTION IN PARTS PER MILLION

Soil treatment	Dates samples taken						Total average for treatment
	Mar. 14, 1931	May 20, 1931	July 23, 1931	Sept. 23, 1931	Nov. 24, 1931	Mar. 13, 1932	
Rye	7.80	5.90	6.76	6.66	6.76	7.15	6.84
Clover	6.82	7.32	6.99	6.99	7.82	8.84	7.33
Vetch	6.48	7.00	7.70	7.76	8.15	8.97	7.68
Fertilizer	8.89	9.25	9.62	9.81	10.00	9.42	9.49
Manure	5.74	6.36	7.15	6.61	6.73	7.00	6.59
Nitrogen	7.84	7.84	8.86	6.92	7.84	8.71	8.00
Check	5.47	7.62	7.62	7.62	7.62	7.62	7.26
Mean average	7.01	7.33	7.81	7.48	7.70	8.24	7.60

The figures shown in Table 2 for phosphates are undoubtedly a little too high. Some silica may have been included as phosphate. However, for comparisons they are reliable and indicate relative values.

There appears to be no well defined seasonal trend or fluctuations as with nitrates. The complete fertilizer treatment gave slightly higher values, which may be significant. The stability of the check plot is noticeable, showing that there has been less interference in ionic relationships than where manurial applications and treatments were made.

Potassium

TABLE 3.—POTASSIUM IN SOIL SOLUTION IN PARTS PER MILLION

Soil treatment	Dates samples taken						Total average for treatment
	Mar. 14, 1931	May 20, 1931	July 23, 1931	Sept. 23, 1931	Nov. 24, 1931	Mar. 13, 1932	
Rye	7	16	6	10	9	7	9.2
Clover	6	14	6	12	10	9	9.5
Vetch	7	12	10	12	7	8	9.3
Fertilizer	7	17	12	12	9	8	10.8
Manure	7	22	10	20	11	5	12.5
Nitrogen	8	25	11	20	11	9	13.8
Check	8	15	12	15	11	8	11.5
Mean average	7	17	10	14	10	7.7	10.9

The values for potassium as given in Table 3 are interesting. The same seasonal trend is followed as with nitrates. Plots growing cover crops show a lower concentration than those otherwise treated. It is especially noteworthy that the nitrogen only application increased available potash over any other treatment. The lowness of the potassium throughout is noticeable and would indicate that any treatment whereby available K is increased would benefit crops.

Calcium

TABLE 4.—CALCIUM IN SOIL SOLUTION IN PARTS PER MILLION

Soil treatment	Dates samples taken						Total average for treatment
	Mar. 14, 1931	May 20, 1931	July 23, 1931	Sept. 23, 1931	Nov. 24, 1931	Mar. 13, 1932	
Rye	70	200	89	86	82	21	91.4
Clover	57	117	50	87	52	24	64.5
Vetch	54	103	82	80	74	22	69.2
Fertilizer	60	151	122	80	106	31	91.7
Manure	75	250	107	136	118	20	117.8
Nitrogen	78	138	108	88	78	32	87.0
Check	74	173	132	76	97	26	96.5
Mean average	67	163	98.7	90.5	86.9	25.2	88.4

The seasonal trend in calcium (Table 4) differs from that of nitrates in that while the May figures are high there is a gradual decline from then on, progressing with the season. The concentration under cover crops is

less than without such treatment. Clover again shows the minimum summer value for this ion.

Magnesium

TABLE 5.—MAGNESIUM IN SOIL SOLUTION IN PARTS PER MILLION

Soil treatment	Dates samples taken						Total average for treatment
	Mar. 14, 1931	May 20, 1931	July 23, 1931	Sept. 23, 1931	Nov. 24, 1931	Mar. 13, 1932	
Rye	7	23	9	7	6	4	9.35
Clover	6	7	6	8	5	4	6.00
Vetch	13	32	14	21	19	3	17.00
Fertilizer	11	29	13	7	9	5	12.33
Manure	7	20	16	13	11	6	12.17
Nitrogen	15	21	27	31	21	15	21.60
Check	5	14	14	8	13	4	9.66
Mean average	9.14	20.81	14.14	13.57	12	6.83	12.60

Magnesium (Table 5) shows the same general behavior as calcium. Values decrease as the season advances. Individual treatments show more variation than they do with calcium. Again clover appears to utilize magnesium more heavily than other crops, whereas vetch uses this element sparingly. Similarly to potassium, the nitrogen treated plots show enhanced magnesium over other treatments.

Sulphates

TABLE 6.—SULPHATES IN SOIL SOLUTION IN PARTS PER MILLION

Soil treatment	Dates samples taken						Total average for treatment
	Mar. 14, 1931	May 20, 1931	July 23, 1931	Sept. 23, 1931	Nov. 24, 1931	Mar. 13, 1932	
Rye	11	22	9	17	11	8	12.2
Clover	10	9	8	8	5	6	7.5
Vetch	17	10	8	8	8	6	9.5
Fertilizer	15	36	36	32	12	7	23.0
Manure	14	13	8	10	7	6	9.7
Nitrogen	10	8	11	11	10	7	9.5
Check	10	10	10	33	11	4	13.0
Mean average	12.4	15.3	12.9	17	9.1	6.3	12.2

The same general trend is followed with sulphates (Table 6) as in the case of nitrates. They are highest in May and September, although there are some slight inconsistencies. The May concentration in some cases is not appreciably greater than that of March, 1931. The complete fertilizer prevented the July minimum value being reached. It would appear that sulphates are not so readily lost from the soil solution during the winter months as are calcium and nitrates. Under clover, again the lowest concentration appears.

Bicarbonates

TABLE 7.—BICARBONATES IN SOIL SOLUTION IN PARTS PER MILLION

Soil treatment	Dates samples taken						Total average for treatment
	Mar. 14, 1931	May 20, 1931	July 23, 1931	Sept. 23, 1931	Nov. 24, 1931	Mar. 13, 1932	
Rye	29	22	37	27	27	29	28.5
Clover	35	27	37	24	24	17	27.3
Vetch	29	17	27	22	22	17	22.3
Fertilizer	39	29	41	24	24	24	30.2
Manure	34	27	27	27	27	29	28.5
Nitrogen	46	44	44	37	37	37	40.3
Check	34	27	29	29	24	24	32.8
Mean average	35.1	27.6	34.6	27	26.4	25.3	30.0

Considerable fluctuation is shown with bicarbonates (Table 7). In general it may be deduced that when ions previously mentioned are high, bicarbonates are low, and vice versa. This ionic relationship applies particularly to the anions NO_3 and SO_4. The plots under cover crop show increased HCO_3 over the others, except that treated with sodium nitrate. The effect of NO_3 in increasing root growth and the resulting added CO_2 production may account for this.

Chlorine

TABLE 8.—CHLORINE IN SOIL SOLUTION IN PARTS PER MILLION

Soil treatment	Dates samples taken						Total average for treatment
	Mar. 14, 1931	May 20, 1931	July 23, 1931	Sept. 23, 1931	Nov. 24, 1931	Mar. 13, 1932	
Rye	32	14	16	14	10	30	19.6
Clover	24	36	12	16	12	34	22 3
Vetch	26	24	14	10	20	28	20.3
Fertilizer	22	48	42	16	12	28	28.0
Manure	20	28	22	18	14	32	22.3
Nitrogen	20	22	16	10	18	26	17.0
Check	24	18	22	12	12	24	18.7
Mean average	24	27.1	20.6	13.7	14	29	22.0

The chlorine ion shows no consistent behavior (Table 8). It is noticeable that it is high during the early spring when other ions are low, so it is probably a product of rainfall. During the summer months cover crops seem to reduce it more than other treatments, and clover more than the other cover crops.

Total Ions

Total ions were measured electrically, Table 9 being a record of the specific resistance offered by the soil solution. The larger the figure the weaker is the concentration of the soil solution.

TABLE 9.—SPECIFIC RESISTANCE (OHMS) OF SOIL SOLUTIONS UNDER DIFFERENT MANURIAL TREATMENTS

Soil treatment	Dates soil samples taken						Total average for treatment
	Mar. 14, 1931	May 20, 1931	July 23, 1931	Sept. 24, 1931	Nov. 24, 1931	Mar. 13, 1932	
Rye	7200	1350	2100	3525	5100	7800	4507
Clover	7800	1950	5700	2100	4500	6700	4786
Vetch	7300	2325	4950	3000	3550	7350	4746
Fertilizer	6900	1125	2250	2100	3150	7950	3920
Manure	7200	1650	2175	1875	2175	6450	3580
Nitrogen	6450	1420	2250	2175	3000	7500	3800
Check	6125	1875	2625	1875	3850	6450	3800
Mean average	7000	1675	3160	2380	3620	7180	4160

The seasonal variation of total ions follows the trend of the nitrates, the total concentration being low in March, high in May, low in July, high in September, and from then on there is a gradual falling to a low point the following March. Clover reduces the available nutrients to a very low figure in July. Rye is not so exhaustive as other green manures while actually growing, but as indicated by September and November measurements, it is not so beneficial when turned in. Complete fertilizer, manure, and nitrogen all prevented the July minimum to some extent, manure showing the greatest effect.

Reaction of Soil Solution

TABLE 10.—pH VALUES OF SOIL SOLUTION UNDER DIFFERENT TREATMENTS

Soil treatment	Dates soil samples taken						Total average for treatment
	Mar. 14, 1931	May 20, 1931	July 23, 1931	Sept. 24, 1931	Nov. 24, 1931	Mar. 13, 1932	
Rye	5.6	5.6	6.0	5.9	5.9	5.6	5.72
Clover	5.6	5.5	6.3	6.0	5.8	5.6	5.80
Vetch	5.8	5.7	6.3	5.7	5.7	5.5	5.75
Fertilizer	6.0	5.9	6.1	5.9	5.9	5.8	5.94
Manure	5.9	5.7	5.7	5.8	5.8	5.9	5.80
Nitrogen	5.9	5.8	6.0	5.8	5.8	5.85	5.85
Check	5.8	5.7	5.7	5.6	5.6	5.80	5.70
Mean average	5.79	5.66	5.97	5.79	5.79	5.71	5.80

Table 10 shows that in general the acidity decreases during the summer. It decreases more under cover crops than without, and less under rye than under clover or vetch.

DISCUSSION

The relatively long period necessary to extract the soil solution in both March, 1931, and March, 1932, shows that at these periods the soil was in a poor physical condition (deflocculated). This deflocculated condition can readily be accounted for by the low calcium content and low content generally of flocculating ions. A fall application of lime should prove very beneficial in preventing this winter poor soil condition.

The rapid leaching in the winter of all nutrients strongly indicates that some method of preventing these losses should be practised in wet, mild climates such as the Lower Mainland of British Columbia. The use of winter cover crops is therefore recommended. Cover crops grown at this time offer no serious competition to the main crop and when the cover crop is plowed under the nutrients used by it, and so prevented from leaching away, are returned to the soil. Planting in the early fall should also give them a good start as the analyses showed large amounts of available nutrients present at this time.

Benefits of Cover Crops.—The less acid soil solution under cover crops, Table 10, is significant. It is now well known that damage due to acidity is often caused, not by the acidity (H-ion) directly, but rather the lowering of the pH brings into solution toxic substances in the soil which under less acid conditions are insoluble and therefore harmless, *e.g.*, aluminum. The extra CO_2 excreted from the roots of the cover crops, as observed in Table 8, increases the bicarbonate ion which must replace, in the soil solution, the absorbed strong acid radicles such as SO_4, NO_3, Cl, etc., with a very weak one. Hence the pH of the solution goes up (*6*).

On the other hand, from unpublished work done in this laboratory there is evidence that cover crops render alkali soils less alkali. Alkalinity often causes damage indirectly by making nutrients insoluble which are needed by the plant. Under such circumstances, making the soil solution more acid by growing cover crops tends to render certain nutrients more available. Iron is a good illustration of a nutrient so affected. In alkali soils even small differences may be very significant. There is no way of making actual determinations on the soil solution immediately at the point of contact with the root. This zone is the important one and the reaction at this point is very probably quite different to the reaction of the extracted solution from the soil as a whole. At this zone of contact CO_2 is bound to be relatively concentrated due to its continued excretion from the root, compared to that which is some distance away. In alkali soils the carbonates which are strongly alkaline usually exist. Passing CO_2 into a solution containing carbonates will change some of the carbonate over to the bicarbonate, and the resulting equilibrium mixture will be fairly close to neutrality. The question arises then as to whether any plant is ever actually feeding in a very alkali medium, even though the pH of the soil may so indicate.

Harmful Effect of Cover Crops.—Due to nutrients being lower under cover crops than under other treatments, the danger of establishing a cover crop in a poor soil where nutrients are low, is obvious. Such a soil should first be built up with barnyard manure or artificial fertilizer before sowing the cover crop. Of the cover crops used, rye seems the least competitive to the main crop, and clover the most competitive.

On soils where inorganic nutrients are not deficient, the advantage of building up humus and improving the physical condition of the soil is well known.

Application of Fertilizers.—On reasonably good soils no spring application, unless a very early one, of readily available nitrogen would appear

to be of value. The May concentration of nitrates (also most other nutrients) is normally high. For crops making growth in June and July, this would appear to be the time when an application of available nitrogen is needed as nitrates are normally very low at this time. This would be particularly true in a soil not especially rich, where cover crops are being grown, where a lawn is in the process of making or being maintained, or in the establishment of any grass lands.

It is of especial interest to note that a spring application of sodium nitrate did not appreciably increase the nitrates in the soil solution in this experiment, but did increase the available potash and, to some extent, the magnesium. This appears to be a base exchange phenomenon where the nitrates went quickly into solution and were used up by the plant roots, whereas the sodium replaced potash from the solid phase of the soil. The potash so released then entered and became part of the soil solution.

The fact that such a situation here occurred leads to the supposition that this may frequently occur on soils, particularly where minerals are not especially deficient. Very probably one of the benefits derived from adding different fertilizers on relatively good soils comes from increasing the potash by the method suggested, rather than by increasing the other elements. Analyses of soils universally show relatively low figures for available potash, whereas the total amounts of potash in agricultural soils is usually high. Any method of increasing the concentration of the potassium in the soil solution would then be expected to give better growth, even where fairly good growth was taking place. Investigations as to methods of releasing the potash already present in the solid phase of the soil should be very fruitful.

Index of Soil Fertility.—While the data obtained in this work are obtained from a soil which shows no deficiency in plant nutrients, nevertheless, this soil is not particularly high in such constituents. It has, however, good recuperative powers in its ability to restock the soil solution, as evidenced by the low March and July figures, followed by the high figures in the May and September analyses. The values obtained then, are considered just about marginal for safety of good growth.

Definite Need Fulfilled.—Finally in this study a very definite need has been fulfilled in that a "yard stick" has now been provided as a basis for a comparison of soils growing raspberries in the Lower Mainland area of British Columbia.

With such a series of analyses available as a standard, it is possible to use these data in comparing the analysis of the soil solution of any soil in the lower mainland where the displacement has been made at the same corresponding time of the year and at the same, or calculated to the same, moisture content as shown in the tables obtained.

If it is found on making such a comparison that any one or more of the nutrients fall much below the values for those nutrients shown in the tables, the particular soil in question is in need of supplementary treatment to increase the concentration of the soil solution in respect to the nutrient deficiencies shown.

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Résumé

Nutrition du framboisier. G. H. Harris et J. J. Woods, Université de la Colombie-Britannique, Vancouver, C.-B.

L'étude dont il est fait rapport portait sur des échantillons de terre pris dans une plantation de framboisiers à Agassiz, C.-B. On a constaté que les principes nutritifs du sol sont rapidement emportés par les eaux en hiver et l'emploi de plantes-abris en hiver est recommandé, sauf sur les sols pauvres. Les applications de nitrate de soude au commencement du printemps n'ont pas beaucoup augmenté la quantité de nitrates dans la solution du sol, mais elles ont augmenté la quantité de potasse assimilable et, jusqu'à un certain point, celle de magnésium. Ces expériences ont été utiles en fournissant un guide touchant les éléments nutritifs nécessaires dans les sols affectés à la culture du framboisier dans ce district.

MALLING STOCKS AND FRENCH CRAB SEEDLINGS AS STOCKS FOR FIVE VARIETIES OF APPLES. I.

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A few years ago it became evident that the Malling vegetatively propagated apple stocks were being found very useful under conditions of soil, culture and climate existing in England. It became imperative, therefore, that the most promising of these clons should be evaluated as stocks for apple trees in Canada.

MATERIALS

In the spring of 1927 the Ontario Horticultural Experiment Station imported from the East Malling Station the following budding stocks: 200 each of Malling XVI, I and II; and 100 of Malling IX. These stocks were budded in August of the same year to five important local varieties, viz., R. I. Greening, Melba, Delicious, Spy and McIntosh, equal numbers of buds of each variety being set in each stock. A good stand of trees was obtained and in the fall of 1929 the best trees of each variety were planted in an orchard in a comparative test with commercial nursery trees on French Crab seedling roots which had been selected for uniformity in the nursery. All of the latter were budded trees except Spy which was grafted on whole roots. Trees on standard stocks, French Crab and Malling XVI, were planted 39 feet apart each way. Filler trees, Malling I and II alternating, were planted only *between* standard rows and not *in* the standard rows, Malling I being semi-standard, *i.e.*, in the centre of the square made by two French Crab trees on one row and two Malling XVI trees[2] on the adjacent standard row. This arrangement allows for an analysis of results by Students' Method, 16 pairs being available for each variety. Trees on Malling IX being few in number were planted at one side of the orchard and are therefore not included in the analysis.

The soil is a fine sandy loam, low in organic matter and readily available phosphorus and potash. The land is slightly rolling and there is a low area cutting across one corner of the orchard. Clean cultivation plus cover crops is the method of culture followed. No manure has been used and the only mineral fertilizer applied was in the spring of 1934: 600 lbs. of acid phosphate and 300 lbs. of sulphate of potash per acre. Some potash starvation symptoms have shown up, particularly in the variety R. I. Greening.

Measurements

No growth records were kept in the nursery. In the spring of 1930 all trees were pruned moderately to encourage the development of satisfactory heads. These prunings were not weighed but since that time weight of prunings from individual trees has been recorded. Trunk measurements have been taken at a marked point above the wire guards

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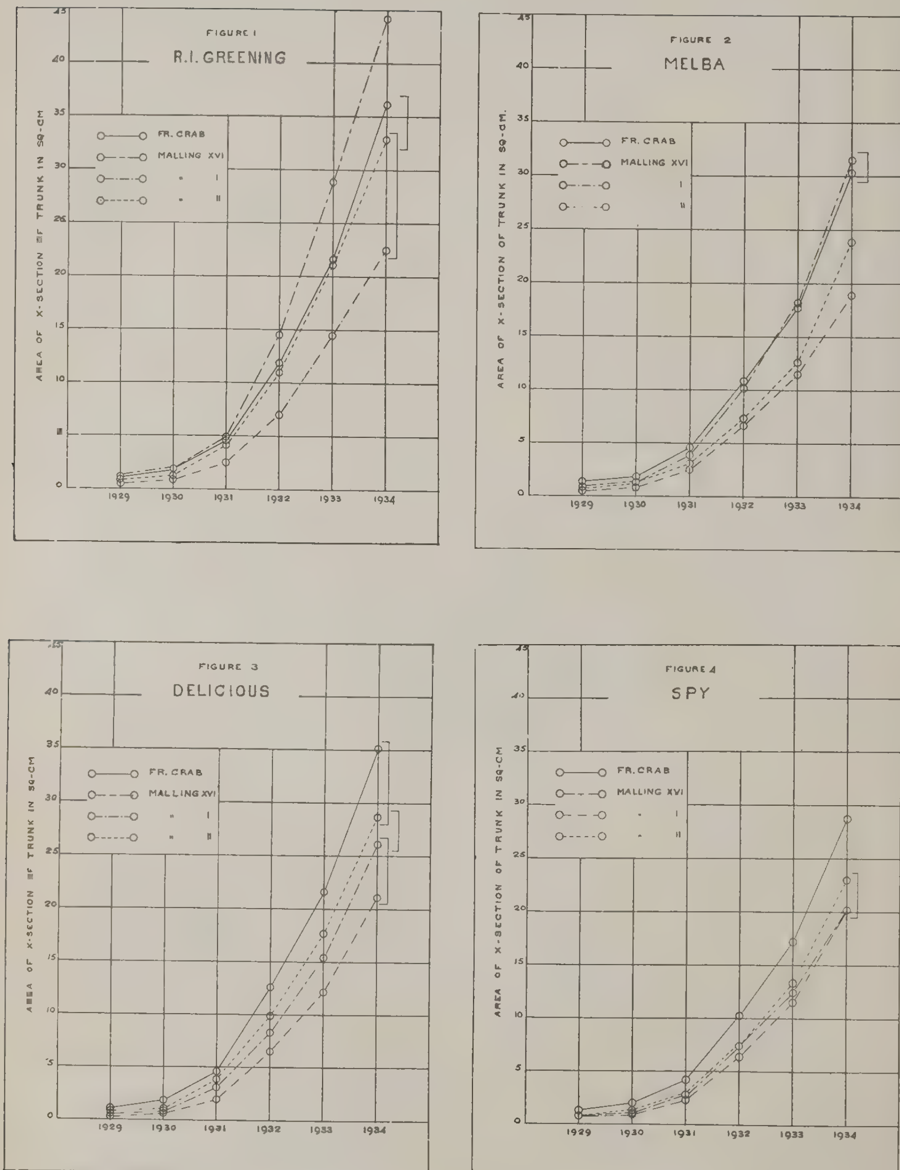
[2] When trees are referred to as French Crab trees, Malling XVI trees, etc., it is to be understood that the trees are worked on these stocks.



FIGURES 1–4. Comparative tree size of R. I. Greening, Melba, Delicious and Spy on four stocks. Yearly total area of cross-section of trunk, means of 16 trees of each variety on each stock being plotted. 1934 measurements within brackets are not significantly different.

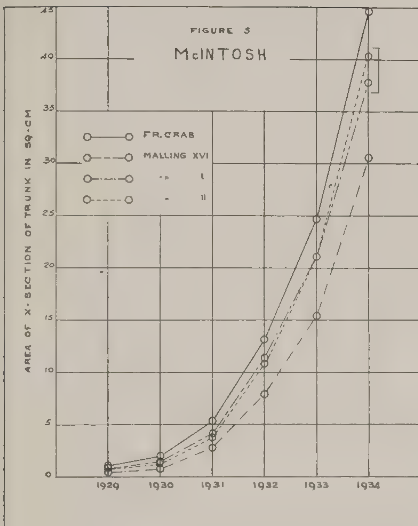


FIGURE 5. Comparitive tree size of McIntosh on four stocks. (Plotted by same method as Figures 1–4).

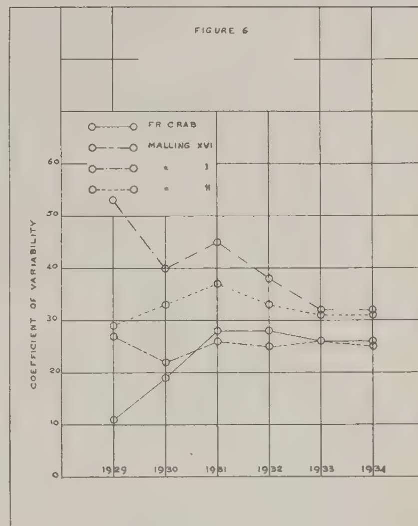
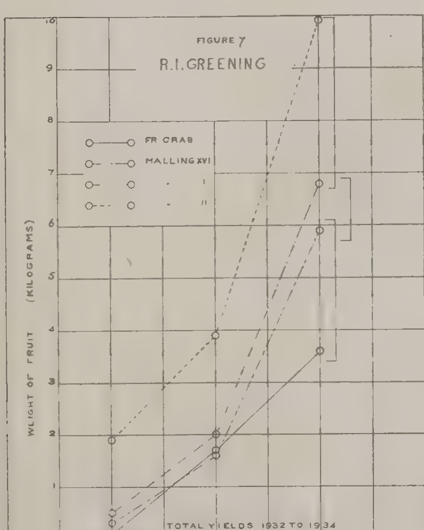
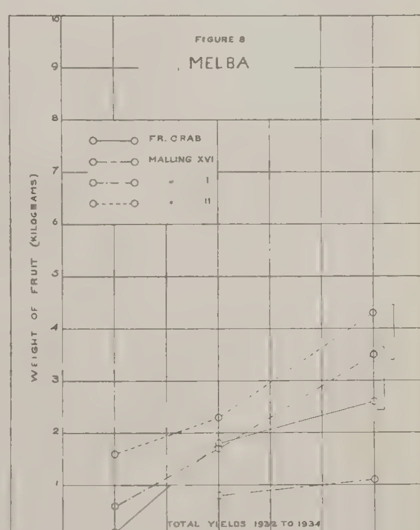


FIGURE 6. Yearly coefficient of variability in tree size, mean of five varieties.





FIGURES 7–8. Total yield of fruit, mean of 16 trees. Total yields up to and including 1934 which are bracketed together are not significantly different.

(rodent protection) about 16 inches from the ground. The area of cross-section of trunk has been computed from diameter and circumference measurements, the latter measure being used during the past three years. Counts of blossom clusters on each tree are being made until the variety begins to bear a measurable amount of fruit. Up to the present time number as well as weight of marketable fruits has been recorded for each tree.

RESULTS

Growth

In so far as area of cross-section of trunk can be used for that purpose, the comparative tree sizes over the five year period are shown in Figures 1–5. Cross-sectional area of trunk is certainly a better measure of comparative tree weight than is circumference (or diameter) as may readily be determined from Table 12 in New York (Geneva) Tech. Bul. 164 (Collison and Harlan). Those stocks which produced trees not significantly different in size at the end of 1934 are bracketed together at the extreme right of the figures. Malling I stock has given the smallest tree with all scion varieties, though in Spy it now equals Malling XVI. Malling I trees grew poorly in the nursery and as a result started in the orchard at a considerable size handicap. In R. I. Greening and Melba, the two most precocious varieties, Malling XVI trees are significantly larger than Malling II trees but in the other three varieties size differences are reversed but not significant. French Crab trees are significantly larger than Malling XVI trees in Delicious, Spy and McIntosh, while in Melba differences are insignificant and in R. I. Greening, Malling XVI trees are significantly larger than French Crab trees even though more fruit and prunings have been taken from the former. On first thought it seems unfortunate that there were size differences between the lots of trees at planting time but it must be pointed out that, with the exception of the French Crab trees, all trees were grown side by side in nursery rows and that therefore size differences in the fall of 1929 were probably characteristic of the stock on this particular soil. Undoubtedly the French Crab nursery trees were grown under better conditions of fertility than the trees on Malling stocks and thus started in the orchard with some slight advantage over the latter. Considering Delicious, Spy and McIntosh varieties French Crab trees are larger than Malling XVI trees but being also larger at planting time, the growth rate over the five-year period in the orchard as determined by the Geometric Mean formula, $\frac{\text{Increase}}{(t_2 - t_1)\sqrt{\text{original} \times \text{final}}} \times 100\%$, is greater for the Malling XVI trees. (Moffat (*1*) has shown that the Geometric Mean formula gives a satisfactory measure of growth rate.)

Growth Rates, 1929–1934.
Based on cross-section area of trunk, each figure being the mean of 16 trees

	French Crab	Malling XVI
Delicious	110	127
Spy	90	96
McIntosh	125	127

In Delicious and Spy the differences are significant, but not in McIntosh. However, the growth rate for the same trees from the fall of 1933 to the fall of 1934 is practically the same for these two stocks. This indicates that while Malling XVI trees tended to catch up to

French Crab trees in the early years in the orchard they have now ceased to grow at a faster rate than the latter. Fruit production has interfered with growth rate in R. I. Greening and Melba to such an extent that the figures would mean very little.

The pruning in this orchard was the minimum consistent with the development of reasonably strong well-balanced heads. All pruning has been done by the writer. Table 1 illustrates the inevitably heavier pruning given to the larger trees within a given variety, there being only one exception, viz., Spy on Malling XVI and Malling II which are very little different in size of tree or weight of prunings. Pruning, therefore, tended to minimize differences in this stock experiment and probably in all other experiments where growth differences are obtained. In a like way pruning is also a factor in reducing the variability of trees within a plot. It is of interest to note that the pruning given these trees has been very much less severe than that given some trees of Lane's Prince Albert of about the same age and size in a stock experiment at the East Malling Station (*2*).

TABLE 1.—WEIGHT OF PRUNINGS, MEAN OF 16 TREES, 1931–34 INCLUSIVE (GMS.)

	French Crab	XVI	I	II
R. I. Greening	369	1053	363	656
Melba	531	538	189	306
Delicious	485	371	239	449
Spy	369	196	134	187
McIntosh	644	396	282	407

Variability

The coefficients of variability in cross-section area of trunk, means of five varieties, are given in Figure 6. French Crab trees started out very much more uniform than the trees on the Malling stocks but during the first two years they increased in variability to a point slightly above the Malling XVI trees and are now only slightly less variable than Malling I trees which were extremely variable when planted. During the past year the coefficient of variability has not changed to an appreciable extent for any of the stocks. It is unfortunate that the trees on Malling stocks were less uniform to begin with than those on French Crab seedlings as this condition makes it hazardous to make comparison as to variability in the orchard. However, in Melba, French Crab and Malling XVI trees, beginning their life in the orchard with C.V.'s of 18 and 20 respectively, had C.V.'s of 32 and 30 in the fall of 1934 indicating that the vegetatively propagated stock, Malling XVI, had only slight effect in making the trees on it more uniform. The writer feels reasonably certain that scion rooting has not been a factor in creating additional variability as he has failed to find more than a mere trace of scion roots on a very few trees.

Yield of Fruit

R. I. Greening and Melba are the only varieties which have produced an appreciable amount of fruit. They began bearing in the third year in the orchard. The comparative yields on the various stocks are shown in Figures 7 and 8, those within a given bracket being insignificantly different in total yield up to and including 1934. Malling II trees have produced

the most fruit but considering their smaller size (Figures 1 and 2) Malling I trees have yielded well. In R. I. Greening, Malling XVI trees have produced more fruit than French Crab trees but positions are reversed in Melba. In Delicious and McIntosh, all stocks ripened a few fruits in 1934 except Malling XVI. Spy has borne no fruit yet.

Malling IX

While the number of trees on Malling IX, classed as a very dwarfing stock, are very small, data on these trees are included here as they furnish some indication of the behaviour of this stock (Table 2). Melba has been dwarfed to a very marked extent, R.I. Greening, Delicious and McIntosh, to a lesser degree and Spy has not been dwarfed at all (See Figure 4) even though it has borne a few fruits beginning in 1932, the third year in the orchard. With all varieties this stock has induced earlier bearing and up to date the yields of R. I. Greening and Melba are a good deal heavier than on any of the other stocks. The fruits are also much better coloured than those from trees on the other stocks. Trees on Malling IX must be kept staked or trellised as the union is not strong. One Delicious tree which became loose from its stake was broken off at the union by wind.

Table 2.—Growth and yield of trees on Malling IX

	No. of trees	Mean area of X-section of trunk 1934 (sq. cm.)	Yield of fruit per tree up to and including 1934 (kgms.)
R. I. Greening	3	18.1	14.5
Melba	6	9.8	10.2
Delicious	3	19.9	5.3
Spy	9	28.7	1.5
McIntosh	4	18.1	4.9

SUMMARY

This is a report on the behaviour of R. I. Greening, Melba, Delicious, Spy and McIntosh on French Crab seedlings, and Malling stocks, XVI, I and II up to the end of the fifth year in the orchard. There are 16 trees of each variety on each stock. Malling I has given the smallest trees, French Crab seedlings have produced the largest trees in three varieties and Malling XVI, the largest trees in two varieties. In three varieties trees on Malling II are larger than those on Malling XVI. Pruning weights show the possible reduction by pruning of (1) growth differences between trees on the various stocks and of (2) variability between trees within a given kind or treatment. Trees on French Crab seedlings which started in the orchard as very uniform trees are now just as variable as the trees on Malling XVI which started out very much less uniform. R. I. Greening and Melba are the only two varieties which have produced an appreciable amount of fruit. In both varieties trees on Malling II have produced the most fruit with Malling I trees coming next in order. In R. I. Greening, trees on Malling XVI have outyielded those on French Crab seedlings but in Melba the order is reversed. At one side of the orchard there are a few trees of the same varieties on Malling IX. This stock has induced different degrees of dwarfing in the various varieties,

has given better yields per tree than any of the other stocks, and produces exceptionally well coloured fruit.

ACKNOWLEDGMENT

The writer wishes to thank Director E. F. Palmer and Messrs. Dickson, Strong and vanHaarlem for advice in conducting this stock test and for assistance in the preparation of the manuscript. To Professor R. C. Moffatt of the Ontario Agricultural College the writer is indebted for advice on measurements and statistical analysis.

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Résumé

Valeur des pousses de Malling et des égrins de pommiers sauvages français employés comme sujets pour cinq variétés de pommiers. 1. W. H. Upshall, station expérimentale d'horticulture, Vineland Station, Ont.

C'est là un rapport de la façon dont se sont comportées, jusqu'à la cinquième année de culture dans le verger, les variétés R.I. Greening, Melba, Délicieuse, Spy et McIntosh, greffées sur des sujets d'égrins de pommiers sauvages français et de Malling XVI, 1 et II. Il y a 16 arbres de chacune de ces variétés, sur chaque sujet. Le Malling I a donné les plus petits arbres, les égrins de pommiers français les plus gros dans trois variétés et le Malling XVI les plus gros dans deux variétés. Dans trois variétés, les arbres greffés sur Malling II sont plus grands que ceux greffés sur Malling XVI. Les poids notés à la taille indiquent la possibilité de réduire par la taille (1) les différences de croissance entre les arbres greffés sur les différents sujets et (2) la variabilité entre les arbres d'une certaine espèce. Les arbres greffés sur les égrins de pommiers français, d'abord uniformes au commencement de leur pousse dans le verger, sont maintenant tout aussi variables que les arbres greffés sur Malling XVI, qui étaient au début beaucoup moins uniformes. Les Greening de R.I. et Melba sont les deux seules variétés qui aient produit une quantité appréciable de fruits. Dans les deux variétés, les arbres greffés sur Malling II sont ceux qui ont produit le plus de fruits; les arbres greffés sur Malling I venaient ensuite. Dans les Greening de R.I., les arbres greffés sur Malling XVI ont mieux rapporté que ceux qui étaient greffés sur les égrins de pommiers français, mais cet ordre est interverti dans le cas de la variété Melba. Sur un côté du verger il y a quelques arbres des mêmes variétés greffées sur Malling IX. Ce sujet a provoqué différents degrés de rapetissement dans les différentes variétés, mais il a donné de meilleurs rendements par arbre qu'aucun des autres sujets et produit des fruits exceptionnellement bien colorés.

THE PRESENT STATUS OF GAS STORAGE RESEARCH WITH PARTICULAR REFERENCE TO STUDIES CONDUCTED IN GREAT BRITAIN AND PRELIMINARY TRIALS UNDERTAKEN AT THE CENTRAL EXPERIMENTAL FARM, CANADA

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INTRODUCTION

The development of gas storage of perishable products has made rapid strides since the Great War when food preservation was a matter of grave concern, with the result that there are at the present time five commercial gas storages for fruit in England having a total capacity of over 1,500 tons.

Although Berard (*2*) in 1821 was presented with a medal by the French Academy of Science for his paper on the lengthened storage life of fruit stored in atmospheres devoid of oxygen, there was very little interest displayed until the early part of this century. In 1907 Fulton (*10*) found that the bright appearance of strawberries was influenced by the tightness of the container as influencing the carbon dioxide concentration. Successful results were obtained by Gore and Fairchild (*12*) in 1911 using carbon dioxide in order to remove the astringency of Japanese persimmons. The effects of nitrogen and hydrogen were investigated by Hill (*13*) in 1913 upon ripe grapes and cherries which he found respired just as rapidly as in air for the first 36 hours of storage. On the other hand green peaches exhibited a depression on respiratory activity when subjected to similar treatment.

Bartholomew (*1*) and Stewart and Mix (*27*) have proved that lack of oxygen produces a toxic condition in the potato known as Black Heart, whilst excessive carbon dioxide concentration according to Shear, Stevens and Rudolph (*25*) causes spoilage and a bitter flavour with cranberries. Brooks and Cooley (*3, 4, 5*) studied carbon dioxide concentration in relation to temperature and noted that concentrated atmospheres of carbon dioxide at 30° C. produced a much more pungent flavour in apples than those stored in the same atmosphere at 10° C. and that the colour developed much more slowly under these treatments than those in air. They also showed that apples stored at 15° C. for five to seven weeks in atmospheres in excess of 5% carbon dioxide developed a pungent alcoholic flavour. Magness and Diehl (*20*) noted similar effects. Thatcher (*28*) studied the effect of carbon dioxide upon raspberries, blackberries and loganberries and was able to increase the storage life by four days and he suggested that internal breakdown of apples might be overcome by the retardation of enzymatic activity.

Oranges stored in excessive concentration of carbon dioxide were found by Onslow and Barker (*22*) to have a much greater alcoholic content than fruits stored in air.

The storage life of Fuerte Avocados was lengthened by one month by Overholser (*23*) who used 4 to 5% carbon dioxide and 4 to 5% oxygen at

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7.2° C. whilst 20 to 25% carbon dioxide prevented softening and failed to spoil the flavour when removed from storage.

Lettuces stored at low temperatures by Nelson (*21*) exhibited spotting which he attributes to the inability of the plant to absorb oxygen at such temperatures. The inhibition of mould and bacterial development during storage of bacon and pork at 32° F. in atmospheres of 100% carbon dioxide has been demonstrated by Callow (*8*). With both these products the flavour was not the least impaired. The importation of pork by this means from Canada to Great Britain has thus been rendered possible, as storage by this method after seventeen weeks produced no ill effects. Similarly anaerobic conditions by means of 100% carbon dioxide have been found by Coyne (*9*) to inhibit the growth of organisms which were isolated from the slime and intestines of fresh fish.

Sharp (*24*) reports that eggs may be kept longer in 3% carbon dioxide at freezing temperatures or in 10 to 12% at room temperature. The effect of the carbon dioxide is to maintain the original pH of the egg white which has a tendency toward alkalinity when stored in air and produces what is known as "watery white." Excessive carbon dioxide concentration will however cause turbidity in the white due to approaching the isoelectric point of protein. Thornton (*29*) using "Dry Ice" or solid carbon dioxide experimented with a great variety of plant material including flowers. Bud development of roses, dahlias and snapdragons varied with different carbon dioxide concentrations. It is interesting to note that he found the buds which were removed from cold storage in air lost their petals quickly whilst the buds stored in gas opened slowly with good colour and shape. He also states that the minimum period of treatment is 3 days and about 7 days as a maximum.

Brook *et al* (*7*) studied the effects of solid and gaseous carbon dioxide upon transit diseases of fruit. They state that in order to inhibit rots such as Botrytis, Rhizopus and Monilia it is necessary to use about a 25% concentration of carbon dioxide. Unfortunately however peaches, apricots, strawberries and raspberries exposed to such a concentration for 24 hours lose their aroma and the flavour is impaired, but lower concentration they maintain would be just as effective in holding the fruit as any method of precooling. This drawback is not so marked with plums, cherries, blackberries, blueberries, black raspberries, currants, pears, apples and oranges, furthermore a high degree of resistance was shown by peas, sweet corn, carrots and grapes. The last named fruit, grapes, did not shatter under such treatment. The treatment also was actually of more value in the retardation of softening than as a preventative against rot development. The authors also point out that the effects noted "were almost entirely due to the carbon dioxide gas, the refrigerating effect of the solid carbon dioxide being largely offset by a slower melting of the ice in the bunkers."

The rate of ventilation was found by Kidd and West (*17*) to greatly influence the rate of ripening of bananas as indicated by the following table.

Rate of ventilation for first 14 days			
Changes per day	15	60	240
Period (days) to ripen	14	16	21

In addition they point out that low percentages of either oxygen (1% to 2.5%) and carbon dioxide (1.5% to 10%) cause considerable retardation of ripening with bananas. The same authors and Trout (*18*) have investigated the keeping qualities of pears. Oxygen concentrations below 2% give marked retardation, a similar effect being produced by carbon dioxide concentration of 15 to 20%. Trout (*30*) also states that by excluding oxygen for a period he was able to extend the storage life of pears to the extent of 50% of the normal for any given temperature.

The Work of Dr. Kidd and Dr. West of the Food Investigation Board of Great Britain

The literature that has been reviewed demonstrates that the greater part of gas storage studies to date is composed of isolated experiments more or less demonstrating the effects of artificial atmospheres upon plant organs. The exhaustive studies of Kidd and West on apples are, however, worthy of special attention because they have now reached the point when definite recommendations as to the gas storage of certain varieties of apples are being adopted with success by commercial fruit growers. Their earlier work (*15*) was concerned with the effects of carbon dioxide and oxygen upon fruit which was stored in containers in which the carbon dioxide was allowed to accumulate, taking advantage of the fact that the rise in carbon dioxide concentration is proportional to the drop in oxygen concentration, the sum always remaining at approximately 21%. The varieties of apples used were Bramley's Seedlings, Chiver's Seedling, Stirling Castle and Lane's Prince Albert and the temperature ranged between 50° and 60° F.

Change in colour from green to yellow was noted and the difference between two varieties may be clearly seen from their results. Stirling Castle were yellow after 28 days and yellow-green after 114 days in an atmosphere containing 5 to 10% oxygen and 10 to 15% carbon dioxide, in the same atmosphere Lane's Prince Albert were quite green after 105 days and yellow stored in air for 35 days. Using a penetrometer or pressure guage they found that the rate of softening of tissue in Stirling Castle apples after 67 days in gas storage was given by a hardness value of 156 units against a value of 106 units with those stored in air. Air stored apples were found to be much sweeter than those stored in gas over the same period, similarly surface wax in the former group had developed to a greater extent.

The authors point out that the retarding effect has a definite limit beyond which such functional diseases as Brown Heart (*14*) and superficial scald make their appearance. The latter disorder was successfully controlled by oiled paper bearing out the findings of Brooks, Cooley and Fisher (*5*, *6*). They worked out the maximum efficiency of gas storage of the apples under experiment against those stored in air based upon, firstly, the mean storage life 50% wastage, and also the commercial storage life 10% wastage, the ratio on the former basis was 1 (air) : 1.64 (gas storage) and on the latter basis, 1 (air) : 2.17 (gas storage) using no temperature control.

Similar trials were then conducted on a semi-commercial scale in co-operation with Messrs. Chivers and Sons at Histon, Cambridge. The

eight ton commercial storage trial is of the most practical interest to us in that the investigators append the cash returns as shown in Table 1.

TABLE 1

Variety	Quantity stored	Wastage	Gross value at time of storage	Selling price	Date of sale
	lb.	%	£ s. d.	£ s. d.	
Bramley's Seedling	7,756	12.5	54 3 0	146 6 0	Mar. 1
Lane's Prince Albert	6,344	34	36 1 0	76 4 0	Feb. 16
Newton Wonder	600	14	4 15 0	11 8 0	Mar. 1
Lord Derby	582	17	3 10 0	13 0 0	Feb. 18
Stirling Castle	3,091	39	16 10 0	15 12 0	Mar. 7
Total	8¼ tons	24	114 19 0	262 10 0	

The authors observed that much less wastage occurred with apples on trays than those in boxes and that oiled paper controlled all scald. Furthermore small apples wasted less than large ones and fruit from grass plots kept better than that taken from cultivated plots. Fungal rotting was also considerably reduced by wrapping each apple.

In this experiment one difficulty was experienced which is of considerable importance to the Canadian grower. The seasonal temperatures may induce early ripening of fruit with subsequent high temperatures during the early storage period and this induces rapid fungal development. Naturally the higher the external temperature and the greater the volume of fruit the more serious is the problem of self heating of the fruit. Again it is noted that humidity under such conditions may become excessive, and they found that if the external temperature is higher than that in the store the water will be precipitated upon the apples, but when the temperature relationship is reversed the water would be deposited on the walls. With regulated ventilation there is also an accumulation of volatile products due to stagnant air conditions.

The greatest difficulty was in the construction of a really gas tight store and the leakage according to Glazebrooke and Griffiths (*11*) was not so much due to the diffusion of gas through the walls as to mass movement of the atmosphere through cracks. Many methods were tried out including aluminium paint, tar naphtha black applied to the concrete walls but the most satisfactory proved to be vaseline smeared over the internal surface and wallpaper soaked in vaseline placed over the layer of vaseline. Even with this method it was found difficult to maintain 10% carbon dioxide without any ventilation whatsoever. As will be seen later Kidd and West eventually used containers made of sheet iron for their work. In this connection the density of storage and the size of the chamber are important aspects (*26*). It was found that in unventilated holds the greater amount of fruit the greater the production of carbon dioxide while the rate of leakage is supposed to be the same with little carbon dioxide. Furthermore a large chamber will attain a higher concentration of carbon dioxide than a smaller one since it is stated "leakage is a surface effect and

gas production a volume effect and the surface/volume ratio of the chamber decreases as its size."

Gas Store and Cold Store.—The investigators state that in these early experiments gas stored fruit at 46.5° F. will keep as well as fruit stored in air at 34° F. but in the case of Bramley's Seedling apples the incidence of breakdown at 34° F. is a serious consideration. The comparative results indicate that mean storage temperatures are most effective with regulated ventilation. But if low temperatures are utilised less oxygen is required and vice versa. Table 2 illustrates the influence of gas mixtures upon the respiration of Bramley's Seedling apples. Later experiments show that fruit taken from gas store will stand up better than those removed from cold store.

TABLE 2

—	Const. temp.	Observed relative average rate of respiration	Inverse ratio	Relative limit of storage life (approx.)
Air store	46.5° F.	1.00	1.00	1.00
Gas store Carbon dioxide, 12% Oxygen, 9%	46.5° F.	0.54	1.85	1.80

Interesting observations were made upon the effect of carbon dioxide concentration in ships' holds carrying fruit (*26*). Accidental ventilation or leakage is increased tremendously by the battery system of refrigeration which entails forced air circulation, whilst there is no such ventilation with the grid system with a subsequent accumulation of carbon dioxide and development of Brown Heart in the apples. Kidd and West show that if there is sufficient accidental ventilation with the grid system the fruit in the centre of the hold will keep as well as fruit away from the centre because in the first instance there is gas storage with high temperatures and in the second instance cold storage in air.

It now remained for Kidd and West to unravel some of the complex issues connected with their previous work and this they accomplished by using one variety of apple, Bramley's Seedling, and storing the fruit in various gas concentrations at different temperatures (*16*). They eliminated the effects of humidity and volatile products by passing a slow stream of the gas through the cabinets which were adjusted to 90% relative humidity in all cases by bubbling through solutions of calcium chloride.

At 1° C. they found that decreased concentrations of oxygen and increased concentrations of carbon dioxide accelerated low temperature internal breakdown and that in all cases storage in all atmospheres at this temperature were less efficient than those stored in air, whereas at 5° C. all showed greater efficiency. The retardation of ripening was more pronounced by increases of carbon dioxide than with reduced oxygen concentration. For this particular variety they recommend storage at 5° C. in an atmosphere containing 10 to 15% carbon dioxide and about 10%

oxygen. By this method the storage life was increased half as long again as fruit stored in air at the same temperature.

The following striking statement is particularly worthy of note. "After thirty-four weeks storage samples of sound fruit were removed to air from atmospheres containing carbon dioxide and oxygen in the following percentage respectively, 5–5, 5–10, 5–15, 10–10 and 10–15 per cent. These apples were then quite green, firm and perfect in appearance and flavour. At the prevailing summer temperatures they remained in excellent condition for a further six weeks after which they were all used for culinary purposes."

The next variety to be tested was Lane's Prince Albert apples (*19*). Sheet iron storage cabinets were substituted for wooden cabinets as used in the previous trials. The flow of gas was also regulated so that at the lowest temperatures the rate was 10 cubic feet per day and at the highest temperatures 40 cubic feet per day. The authors in this work classify the criteria as to condition of fruit which is of distinct practical value.

(1) Ground colour.
(2) Firmness of flesh.
(3) Scald estimated as *(a)* percentage prevalence, *(b)* intensity as percentage of surface affected.
(4) Browning of flesh tissues *(a)* brown heart type, *(b)* breakdown type, *(c)* core flush type. These are measured as prevalence and intensity, the latter measured as percentage of median transverse section of the fruit.
(5) Fungal rots.
(6) Aroma, flavour and cooking quality.
(7) Wilting.

It was inadvertently found in these experiments that a short exposure to high concentrations of carbon dioxide, namely, 15%, produced a high percentage of breakdown and scald even as much as fruit exposed continuously.

The investigators state that although high concentrations of carbon dioxide are chiefly responsible for functional disorders oxygen exerts a partial influence. This effect is best seen where the amount of injury is greatest, namely, when 15% carbon dioxide is present. As another example of the keeping qualities of fruit after being subjected to artificial atmospheres Table 3 is included showing the condition of fruit removed to 60° F. after being stored at 39° F. for 206 days in various gas mixtures.

TABLE 3

Percentage		Percentage rots	Condition
Oxygen	Carbon dioxide		
2.5	5	25	Sweet, juicy, crisp, firm and ripe
5	5	50	Sweet, juicy, crisp, firm and ripe
10	10	50	Very soft, juicy, full ripe
Air		100	

Kidd and West again find with this variety of apple, Lane's Prince Albert Seedling, that gas storage at 1° C. is of no value and the conditions recommended for the variety is a temperature of 39° F. (4° C.) with an atmosphere containing 2.5% oxygen and 5% carbon dioxide. This treatment was found to be twice as effective as storage in air at 39° F. The authors conclude their investigations upon this particular variety of apples with some observations upon the influence of artificial atmospheres as affecting the chemical constituents of the apple. These are summarised as follows in their paper:—

(1) Increased carbon dioxide retards loss of carbohydrates, 5% gives greater retardation than 10 or 15%.

(2) Increased carbon dioxide appears to accelerate acid loss.

(3) Reducing the concentration of carbon dioxide has little effect upon loss of carbohydrates and acid loss.

(4) Increased carbon dioxide retards loss of alcohol insoluble material.

(5) Reducing oxygen concentration retards loss of alcohol insoluble material.

(6) Increased concentration of carbon dioxide accelerates the hydrolysis of cane sugar.

(7) Reducing the concentration of oxygen has little effect upon cane sugar hydrolysis.

GAS STORAGE STUDIES CONDUCTED AT THE CENTRAL EXPERIMENTAL FARM

In the summer of 1933 it was decided to test the efficiency of gas stored fruit. For this purpose a portable gas analysis apparatus (Orsat) was bought, accurate to 0.2%. A large wooden cabinet was specially constructed for gas tightness and contained four separate chambers with a capacity of 3 cubic feet. All the walls were composed of two layers of wood and oiled paper placed in between which was thoroughly coated with vaseline. The inside walls were then coated with parawax. The front of each chamber was removable and was bedded into a sunken opening which was covered with a thick layer of vaseline. After the chambers were filled the fronts were placed into position and screw clamped as tight as possible. Metal tubes were placed on each side of the four chambers for running in and drawing off the artificial atmospheres.

It was felt that more than one temperature should be used for the work and as the efficiency of the cabinet had not been gauged fully, 5 gallon lime sulphur cylinders were also utilised. The necessary aperture was made by cutting out the base, lining the walls with a wooden frame into which fitted a wooden lid and a rubber gasket was placed in between. The bung hole at the other end of the cylinder was closed with a rubber stopper through which two glass tubes were drawn for inlet and outlet purposes. No attempt was made in 1933 to make up artificial atmospheres of specific concentrations of the three component gases in air, instead various concentrations of nitrogen and carbon dioxide were used. In the first experiment (Trial 1) two varieties of strawberries were used, one box of each variety being placed in the cylinders which were placed under common storage conditions (60° F.). All fruit used in these investigations was

carefully selected for quality and was stored immediately after picking. Two cylinders were used, the initial internal atmospheres of each contained 100% and 92% nitrogen respectively and the object was to study the development of mould under such conditions.

Table 4 shows the subsequent gas analysis observation together with the percentage mould development at the end of five days.

TABLE 4.—PERCENTAGE GAS CONCENTRATION AT VARIOUS DATES AND MOULD DEVELOPMENT USING TWO VARIETIES OF STRAWBERRIES
(Commenced 30/6/33)

Cylinder	Gas	Per cent gas concentration			Per cent mould development, 4/7/33	
		30/6/33	3/7/33	4/7/33	Charles	Lilian
1	N_2	100	91.6	89.8		
	CO_2	—	7.0	10.0	25.0	46.0
	O_2	—	1.4	0.4		
2	N_2	92	91.0	89.8		
	CO_2	—	9.2	10.0	11.3	22.5
	O_2	—	0.8	0.2		
Check	Fruit stored in air				67.2	46.3

Whilst it is difficult to place much reliability on the data in Table 4 in view of the leakage it serves to demonstrate that in the variety Charles mould development was considerably checked. The difference between the results obtained from the cylinders cannot, however, be attributed to the concentration of nitrogen or of oxygen. It might be assumed that the respiratory activity of these fruits stored in 92% nitrogen was initially greater than those stored in 100% with a consequent increase in carbon dioxide concentration which would thus account for the lower percentage of moulds in Cylinder No. 2. This experiment demonstrated the difficulty of obtaining gas tight conditions as it was found impossible to include the results of a third cylinder.

The next experiment also using strawberries, variety Grace, was conducted with a view to ascertaining the effects of very high and low concentrations of carbon dioxide. The carbon dioxide as will be seen from Table 5 was reduced to a minimum by the use of soda lime.

From Trial 2 the findings of earlier workers (*7*, *10*, *29*) are corroborated, namely, that small fruits become very bitter when exposed to high concentrations of carbon dioxide but that such atmospheres maintain the original fresh appearance of strawberries. High nitrogen concentrations appear to have a deleterious influence upon the keeping qualities of the fruit as shown by the fruit stored in nitrogen plus soda lime. It would appear therefore that low concentrations of oxygen and an increase of carbon dioxide not exceeding 10% would be effective in lengthening the storage life of strawberries, nevertheless more critical experiments should be conducted to ascertain the optimum concentration of carbon dioxide. "Sweating" of small fruits is a serious factor in storage, and as may be

TABLE 5.—PERCENTAGE GAS CONCENTRATION AT VARIOUS DATES AND FINAL CONDITION OF STRAWBERRIES STORED IN CYLINDERS AT 48° C.
(Commenced 5/7/33)

Cylinder	Date	Percentage of gases			Condition of fruit 10/7/33
		CO_2	O_2	N_2	
1	5/7/34	82.0	1.0	17.0	Very bitter taste but appearance very good.
	6/7/34	34.0	11.4	54.6	
	7/7/34	16.8	12.65	70.55	
	8/7/34	11.0	15.8	73.2	
	10/7/34	7.9	16.8	75.3	
2	5/7/34	0.1	3.6	96.3	Soft and poor condition, wet.
	6/7/34	0.1	5.9	94.0	
	7/7/34	0.1	10.7	89.2	
	8/7/34	0.1	12.5	87.4	
	10/7/34	0.1	16.4	83.5	
3	4/7/34	0.95	2.2	96.85	Poor taste but better condition than fruit in No. 2 cylinder.
	6/7/34	4.1	0.2	95.7	
	7/7/34	4.75	0.35	94.9	
	8/7/34	6.0	1.4	92.6	
	10/7/34	8.5	0.2	91.3	
Check in air	Not so wet as fruit in No. 2 cylinder but in very poor condition.				

seen from Table 5 higher concentrations of carbon dioxide apparently influence this particular characteristic of senesence as the bright appearance is maintained.

In the next experiment, Trial 3, the wooden cabinet was utilized and various concentrations of carbon dioxide used. Two boxes of Clare strawberries and one box of Newman raspberries were placed in each of the four chambers which had a cubic capacity of 92 litres each. The fruit was subjected to the following treatments at 40° F.:—

No. 1 chamber contained air and was sealed.
No. 2 chamber flushed with 69 litres carbon dioxide.
No. 3 chamber flushed with 46 litres carbon dioxide.
No. 4 chamber flushed with 9.4 litres carbon dioxide.

The trials commenced on 12/7/33 and Table 6 shows the percentages of carbon dioxide and oxygen recorded during the period of treatment.

TABLE 6.—PERCENTAGES OF CARBON DIOXIDE AND OXYGEN IN STORAGE CABINET ON VARIOUS DATES CONTAINING RASPBERRIES AND STRAWBERRIES
TRIAL 3. (Commenced 12/7/33)

Chamber	Gas	13/7	14/7	15/7	16/7	17/7	18/7	19/7	20/7
1	CO_2	3.3	6.0	8.4	10.4	11.6	12.6	13.8	14.6
	O_2	15.3	18.6	17.0	16.4	15.4	15.0	13.2	13.0
2	CO_2	58.0	52.5	47.8	43.4	40.6	37.8	35.5	33.2
	O_2	7.0	9.5	9.7	11.6	10.9	11.4	11.7	11.8
3	CO_2	38.6	35.8	32.8	29.8	28.0	26.4	25.0	23.8
	O_2	12.7	12.9	12.8	13.2	13.5	13.4	13.6	13.6
4	CO_2	12.8	12.4	12.6	12.5	12.5	12.8	13.0	13.6
	O_2	17.0	18.0	16.8	16.0	15.9	15.6	15.2	14.6

FIGURE 1. Fungal development on raspberries stored in various concentrations of carbon dioxide at 40° F. after 8 days. 1. Check—stored in air of cold storage chamber; 2. Air in gas tight chamber No. 1 (sealed); 3. 12% carbon dioxide in gas tight chamber No. 4; 4. 38% carbon dioxide in gas tight chamber No. 3.

The leakage from the cabinets was very pronounced and the flavour was not impaired by high concentration of carbon dioxide which is inexplicable in view of other results obtained elsewhere. The appearance of the berries in all series was very much the same presumably due to the relatively high concentrations of carbon dioxide used throughout. Nevertheless as the accompanying illustration (Figure 1) will clearly demonstrate, mould growth is inhibited by increased concentration of carbon dioxide. Figure 2 also illustrates the rise and fall of concentrations of carbon dioxide and oxygen respectively of the atmosphere in a closed chamber containing fruit. This illustrates the possibilities of using controlled ventilation for commercial storage.

The final test in 1933 was with Newman raspberries using both the cabinet and the cylinders, the former at 32° F. and the latter at 54° F. The fruit was stored in artificial atmospheres 21/7/33 until 1/8/33, two boxes in each cylinder and four in each chamber of the cabinet. Half the fruit was picked off a mulched area and the other half from a cultivated area but no specific differences in reaction were observed relative to cultural treatment. The object of this experiment was to try and correlate temper-

ature effects with atmospheric effects. The following percentages of carbon dioxide and nitrogen were used:—

54° F.	No. 1 cylinder	50% dioxide
	No. 2 cylinder	75% dioxide
	No. 3 cylinder	100% dioxide
	Check in air	

32° F.	No. 1 chamber	100% nitrogen
	No. 2 chamber	50% carbon dioxide
	No. 3 chamber	75% carbon dioxide
	No. 4 chamber	100% carbon dioxide
	Check in air	

The high concentration of carbon dioxide caused the flavour to become very bitter and also the fruit colour changed from red to light pink. The nitrogen treatment produced no ill effects; apart from loss of flavour the fruit kept firm and dry in contrast to strawberries kept under similar condition. It will be remembered that with strawberries the fruit kept dry in high concentrations of carbon dioxide; furthermore strawberries store better at higher temperatures than raspberries which indicates that entirely different storage conditions are necessary for each of these fruits. Again the mould growth was controlled by carbon dioxide at high temperatures; furthermore the check at 32° F. proved to be the best of the series in all respects.

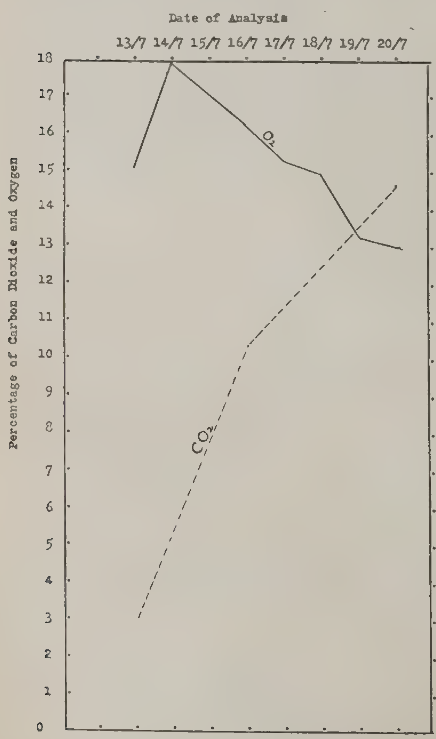

FIGURE 2. Raspberries stored in ordinary atmosphere (Trial 3). Percentage of carbon dioxide and oxygen in gas tight chamber.

It was decided in 1934 to equip so that specific mixtures of carbon dioxide, oxygen and nitrogen could be made up. Accordingly cylinders were obtained and the mixtures placed in them by adding each gas under pressure. Only one experiment was conducted with small fruits. It was found that large containers were unsatisfactory because of the large quantities of gas mixture required to keep the atmosphere in the proportion required. An attempt was made to draw a partial vacuum in the wax-lined cabinet but this procedure only increased the number of leaks. This was also tried on tin cans but they collapsed. The only alternative

therefore was to flush the container with the mixture, which as stated before is wasteful. Thus it was decided that for small fruits 1 litre Erlenmeyer flasks could be used. These were fitted up with two-way stoppers, and approximately twenty-five berries, Variety 21-0745, placed in each, the following mixtures were used at three temperatures, 32° F., 36° F. and 40° F.

(1) 5% CO_2—15% O_2
(2) 10% CO_2—10% O_2
(3) 15% CO_2— 5% O_2
(4) 20% CO_2— 0% O_2

It will be seen from Table 7 that a much more uniform gas content was maintained than in any of the previous attempts when repeated flushes with the mixture were carried out.

TABLE 7.—GAS ANALYSIS OF SERIES AT 36° F. RASPBERRIES STORED IN ARTIFICIAL ATMOSPHERES

No. of mixture	Gas	Original mixture 17/7/34	18/7	Flushed 20/7	21/7	23/7	Flushed 25/7	Flushed 28/7	30/7
1	CO_2	5.0	6.3	5.2	5.2	7.0	8.4	10.2	9.7
	O_2	12.6	12.1	12.6	11.8	10.8	9.0	8.2	8.4
2	CO_2	10.4	11.8	10.5	10.6	12.4	12.6	*	14.3
	O_2	9.6	8.4	9.1	9.4	7.8	6.5		6.9
3	CO_2	15.0	14.2	15.1	15.2	14.8	14.0	15.4	15.6
	O_2	4.4	5.8	4.2	4.2	5.6	5.3	6.0	4.5
4	CO_2	20.0	20.1	20.6	20.6	21.4	*	20.05	20.5
	O_2	1.9	1.1	1.7	1.6	1.4		1.2	1.5

*Mixture exhausted.

The berries stored at 32° F. in an atmosphere containing 5% carbon dioxide and 15% oxygen kept for thirteen days in good condition whilst the second best treatment was 10% carbon dioxide and 10% oxygen at the same temperature. In this latter treatment the only setback was a slightly abnormal flavour.

The control of moulds is efficient at 32° F. in ordinary atmospheres but it was observed that they developed freely at the higher temperatures, namely, 36° F. and 40° F. Furthermore repression of such mould development by the artificial atmospheres used in this experiment showed that only concentrations of 15% and over of carbon dioxide were effective. Unfortunately at all temperatures used abnormal flavours became evident with a carbon dioxide concentration of 10%. It may therefore be concluded that with temperatures of 36° F. and above no specific concentrations of carbon dioxide are of value in lengthening the storage life, the limiting factors being mould development and bitterness of flavour.

It has also been shown in previous trials that atmospheres almost devoid of oxygen are not instrumental in controlling moulds on strawberries and that this same condition is productive of poor flavour with raspberries. It may thus be inferred that very low oxygen concentrations

and high concentrations of carbon dioxide are undesirable in regard to flavour.

These tests have shown that at 32° F. a concentration of 5% carbon dioxide produces no ill effects but that 10% causes slight loss of flavour. It will be observed however in Table 7 that toward the end of the test the carbon dioxide concentration had risen from 10 to 14%. Such an increase it may be suggested would bring about the slight abnormal flavours noted. In view of the observed decrease in "sweating" and maintenance of the bright appearance of raspberries as associated with high carbon dioxide concentrations it would appear that fruit stored in a maximum concentration of this gas relative to flavour, would be under optimum conditions. Such preliminary trials indicate that carbon dioxide in concentrations between 5 and 10% and corresponding percentages of oxygen would be suitable for the storage of small fruits. Further critical experiments should be conducted in order that more specific gas concentrations might be determined.

SUMMARY AND CONCLUSIONS

The defects and difficulties in connection with some gas storage trials have been reported and discussed and it appears that glass, galvanized iron or metal containers are the only efficient materials for "gas tight" storage.

Sufficiently accurate gas mixtures may be made up by passing the component gases into a stock cylinder under pressure. Great difficulty was experienced in maintaining the mixture over fruit under stagnant conditions in large containers and heavy wastage of the gas mixture was entailed by flushing. The only alternative under such conditions would be to pass a slow stream of the artificial atmosphere continuously over the fruit. Regulated ventilation may be used to control the carbon dioxide concentration over stored fruit.

Trials with small fruits in artificial atmospheres showed that pure nitrogen had a very deleterious effect upon strawberries at 54° F. Raspberries lost their flavour in such an atmosphere at 32° F. but otherwise remained in good condition. Very low concentrations of oxygen produce a deleterious effect upon the flavours of both strawberries and raspberries. Mould development may be controlled by storing these fruits at 32° or in concentrations of carbon dioxide of 15% and above.

High concentrations of carbon dioxide were found to decrease "sweating," softening, mould growth and to maintain the bright appearance of strawberries and raspberries. Nevertheless both fruits took on bitter flavours under such conditions and raspberries tended to turn pink in colour. With raspberries in order to maintain original flavours 10% carbon dioxide is the maximum storage concentration and best results were obtained with these fruits when stored at 32° F. in atmospheres containing 5% carbon dioxide.

ACKNOWLEDGMENT

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Résumé

La situation actuelle des recherches sur la conservation au gaz avec mention spéciale des études conduites en Grande-Bretagne et des essais préliminaires entrepris à la Ferme expérimentale centrale, Ottawa, Canada. C. A. Eaves, station expérimentale fédérale, Kentville, N.-E.

Les difficultés rencontrées au cours de certains essais de conservation au gaz sont signalés dans cet article et il appert que les contenants de verre, de tôle ou de métal sont les seuls matériaux qui puissent retenir le gaz. On peut obtenir des mélanges de gaz suffisamment exacts en faisant passer sous pression les gaz constituants dans un cylindre. Dans des conditions stagnantes, et dans de grands contenants, on a éprouvé de grandes difficultés à maintenir le mélange sur les fruits, et l'introduction d'une masse de gaz a entraîné de grosses pertes du mélange. La seule alternative dans ces conditions serait de faire passer un courant lent et continu de l'atmosphère artificielle sur les fruits. Une ventilation contrôlée peut être employée pour régler la concentration du gaz carbonique sur les fruits entreposés. Les essais effectués sur de petits fruits, dans des atmosphères artificielles, ont fait voir que l'azote pur exerce un effet très délétère sur les fraises à 54 degrés F. Lorsque l'atmosphère est à 32 degrés F., les framboises perdent leur goût, mais elles restent en bon état sous d'autres rapports. Des concentrations très faibles d'oxygène produisent un effet délétère sur le goût des fraises et des framboises. On peut enrayer le développement des moisissures en conservant ces fruits à 32° ou dans des concentrations de gaz carbonique non inférieures à 15%. On a constaté que de fortes concentrations de gaz carbonique diminuent le ressuage, l'amollissement, la croissance des moisissures et conservent l'aspect brillant des fraises et des framboises. Cependant, ces deux sortes de fruits ont contracté un goût amer dans ces conditions et les framboises avaient une tendance à prendre une couleur rose. Sur les framboises la concentration maximum de gaz carbonique qui permet de maintenir le goût est de 10% et on a obtenu les meilleurs résultats avec ces fruits lorsqu'ils étaient entreposés à 32°F., dans des atmosphères contenant 5% d'acide carbonique.

CIDER AS A FRUIT PRODUCT[1]

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The surplus production of apples in this country in the past few years has created a definite problem. If the production of apple cider would absorb a part of this surplus, the advantage would be quickly felt in higher prices for apples and the profitable sale of culls and windfalls to the fruit products plants. The difficulty producers have in selling their apples on a glutted market, demands a reduction of surplus apples. This might be accomplished by reducing production, but better still by utilising the surplus in producing other products.

Possibilities of Using Surplus for Cider

The advantages of having a market specifically demanding culls and windfalls becomes obvious in that the grower can rely on disposing of this quality of fruit without having to dump it on the general market in competition with his graded stock. The fact that the cost of handling would be cheap is not to be overlooked, since picking, in most cases, could be reduced to shaking the fruit from the trees. No elaborate grading or packing would be necessary; the same barrels could be used repeatedly for packing and shipping. Furthermore the cider factory would naturally be situated near the apple growing district so that shipping charges would be reduced to a minimum. Such things as insurance, sales agents, storing, etc., would not need to be considered.

Many of the fruit products plants in Nova Scotia have been buying culls and windfalls for as little as twenty to thirty cents a barrel. If used for cider a barrel of apples will yield eight to ten gallons of juice. If the juice is processed into cider, bottled and retailed at the same price as beer, namely fifteen cents a small bottle, then our barrel of apples will have reached a retail value of approximately $15. The possibilities here become obvious at once. A demand for culls and windfalls would raise the price to the grower and still leave plenty of opportunity for the profitable manufacture of cider, especially so since the cider maker hasn't the same overhead as the canner who must consider the cost of individual handling, coring, peeling and trimming for each apple. Furthermore, apples being delivered to the cider plant need not be segregated into varieties as is the case in the canning plant. The varieties can be more or less freely mixed when pressed without doing harm to the cider for, as will be pointed out later, judicious blending and processing can be made to bring up the flavour and quality appreciably.

While dealing with these possibilities of using surplus apples for cider the following information will prove interesting. The distribution of the Nova Scotia commercial apple crop from 1928 to 1932 shows a substantial amount going to fruit products factories. Of the apples processed, cider accounted for approximately 7% in 1928; 8.5% in 1929; 55% in 1930; 42% in 1931; and 58% in 1932. If this increase in the use of apples for

[1] Paper presented before the Horticultural Group at the C.S.T.A. Convention at Macdonald College, June 27, 1934.

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cider manufacture continues and spreads to the other apple-growing provinces the cider industry will assume considerable importance not only to consumers but to the growers.

Historical

Cider was made in early times and was quite a common beverage for —"The ordinary course among the lower class was to breakfast and sup with toast and cider through the whole of lent." Of course the cider was a rough drink often made from crabs and wild apples. Towards the end of the eighteenth century when continental wars prevented the importation of wines, cider production became an object of national importance and a patriotic duty. As a result great English cider orchards of the southwest came into being.

There were two kinds of cider made at this time, one of a superior quality made from the first brew and served in the best establishments; the other was termed "ciderkin" a weaker cider made by the addition of water to the "must" and was given to the men at work in the fields. With the application of a tax on the orchards and their produce many orchards were uprooted or allowed to decline. The cessation of the Napoleonic war further aggravated the situation since foreign wines were again able to compete with the home product. As a result the quality of cider greatly deteriorated.

Fortunately, the pendulum has swung the other way. Cider has become a high-quality beverage and a favourite drink with people of all classes. The production shows a steady increase until now the annual consumption of cider in England is estimated at about two gallons per capita. Due to the importance cider has achieved in England, definite cider varieties have been developed and grouped into different classes. Kingston Black, Tom Putt and Foxwhelp are among the best known of the sharp class. Morgan Sweet, Improved Pound and Sweet Alford belong to the sweet class. Then Cherry, White Norman, Chissel Jersey, Knotted Kernel and Dabinett are included in the bitter sweet class. However, English cider is not made exclusively from such varieties. Cull apples are very largely used being blended with juices of the above mentioned varieties.

Possibilities of Utilising Common Dessert and Cooking Apples for Cider in Canada

One might naturally think, since some of the prominent varieties of apples used exclusively for cider making in England have been pointed out, that we should find it necessary to develop special varieties for cider making in Canada. It is not felt that this is necessary; it is possible to use the ordinary run of orchard culls and surplus apples. True, such a mixture may be unsatisfactory as such, but, we have found that some varieties of crab-apples give juices which are splendid for blending. We have used such varieties as Martha, Quaker Beauty, Lymans Prolific and Burgess with satisfaction. Even the fruit of some ornamental crabs were excellent for this purpose.

Another likely reason for not cultivating varieties of cider apples such as those grown in Europe is the possible difference in national tastes. The

popular ginger-ales in Great Britain do not meet with favour in this country and similarly the type of cider which may prove most popular here need not be the same as that of England, France or Germany.

Some Methods of Cider Making

There are different methods of making cider which are briefly described, and some attention is given to the method used in the fruit products laboratory at Ottawa.

Vat Fermentation

This method is usually employed to make cider for home consumption or producing bulk cider. The fundamentals consist of pressing the fruit, filtering the juice, fermenting in vat either by inoculation or with natural yeast and racking it off into a clean barrel when it has reached the correct stage for drinking. There are various elaborations which the maker may develop for altering the flavour and quality to his own taste.

Bottle Fermentation

Bottle fermentation is the method most commonly used in European countries for making bottled cider and especially champagne cider. The essential steps are pressing the fruit, blending the juices and storing in large fermenting vats. The rate of fermentation, as denoted by the specific gravity, is carefully watched. When the specific gravity has dropped to about 1.030, which is about five points above the final gravity desired (namely 1.025), the cider is racked off, filtered and bottled. The bottles are then placed in a cool room while the small amount of yeast in each bottle slowly carries on fermentation and charges the cider with carbon dioxide. In some cases the sediment is left in the bottle or it may be removed by disgorging or by chilling the cider and pouring the clear cider into fresh bottles. Each producer of course has his own especial method of blending and processing.

Cold Pack Method—Closed Cuvee Process

In the fruit products laboratory at Ottawa we use the Closed Cuvee Process and believe that it holds the best possibilities for cider making in this country. No hard and fast routine is laid down but a fairly regular procedure is as follows.

Pressing.—The fresh fruit is dumped into a large tank of water which is kept agitated. The clean apples are then paddled onto a pulley which conveys them to the press. They are crushed into a pomace which is dropped in layers about one inch thick onto press-cloths. The cloths are folded over completely enclosing the pomace. A series of these layers of pomace (usually six) is built up one on top of the other and each separated by an open lattice press-board. Such a series, or cheese, as it is termed, is placed under the hydraulic press for about twelve minutes.

Storage.—The expressed juice may be clarified by passing through a high-speed centrifuge, then through either an asbestos pulp prefilter or a plate filter using diatomaceous earth as a filter-aid. The delivered juice is clear and free from all visible suspensions. A further filtration through Seitz E. K. plates completely sterilizes the juice allowing it to flow into a sterile vat where it may be held indefinitely in a sterile condition.

If sterilization is unnecessary the juice is pumped into vats directly from the press and fermentation permitted to proceed until hard cider is

formed. Hard cider can be kept wholesome for months provided the vats are kept clean and completely filled so that no air can enter.

Blending.—When preparing a batch of cider for bottling the first step is to make up the desired blend. Measured quantities of the various juices are thoroughly mixed together until the desired appearance, flavour and body are secured. After determining the difference between the alcoholic content of the blend and that desired sufficient applejuice concentrate is added to make up the difference and give a finished product of about 1.025 specific gravity.

Correctives and Clarifiers.—After making up the blend it may be found that the acidity is too high. This can readily be overcome by adding sufficient calcium carbonate to reduce the acidity to between 0.45% and 0.5% malic acid, which is the normal acidity for bottled cider.

It may often be found, too, that the colour is far too deep and dark so that some clarification and colour reduction are necessary. There are several ways of doing this, but the most common and satisfactory is by fining which is accomplished by adding definite quantities of tannin and gelatine in separate solutions. Usually stock solutions of each are made up and definite amounts of each added to separate samples of cider to determine which proportions of tannin and gelatine give the best results.

Immediately on adding the fining materials a sludge forms which gradually settles to the bottom carrying with it most of the suspended material and a large amount of colouring matter. In a few hours a light transparent cider remains which is easily drained off.

Final Clarification and Sterilization.—The blended cider is next passed through the centrifuge to remove most of the sediment resulting from fining. Any sediment remaining is removed by a prefiltration either through asbestos pulp or a filter aid such as diatomaceous earth.

Sterilization is accomplished as previously described, namely through Seitz-filter containing asbestos sterilizing discs after sterilizing the filter with live steam. The sterilized cider is placed in a sterile vat to undergo fermentation.

Inoculation and Fermentation.—About one week before making up the blend a giant yeast culture is started by inoculating a small flask of sterile cider or sugar solution either from an agar slope or stock solution culture. When fermentation is proceeding rapidly the contents of the flask are added to a demijohn containing about 5 gallons of sterile cider. Then when fermentation becomes rapid (in about three or four days) the whole culture is added to the prepared blend. Fermentation usually proceeds rapidly, and a constant check is maintained by specific gravity readings.

Fermentation Tank.—When the specific gravity has dropped to about 1.035 the cider is pumped into a large glass-lined, steel pressure tank. Here, fermentation continues until the specific gravity has dropped to the required point, usually about 1.025 and since the tank is completely closed the carbon dioxide evolved builds up a pressure usually to about 60–70 pounds per sq. in. Occasionally fermentation may slow down while the cider is in the fermenting tank in which case it is often possible to hasten it by placing a small auxiliary heater under the tank to hold temperature at 75°–85° F.

Brine Cooling Tank.—When the proper specific gravity has been reached the cider is filtered through the Seitz prefilter into the cooling

tank which is a glass-lined, steel tank exactly the same as the fermenting tank but with an outer jacket. However, before transferring the cider a pipe-line is connected to the top valves of each tank and the compressed CO_2 in the fermenting tank passes through until the pressure in the two tanks is the same. Then the cider is pumped through the filter under counter pressure. The filtration clarifies the cider and removes most of the yeast sediment. The cooling tank is then charged with CO_2 to bring the pressure up to 50–60 pounds per sq. in. and cold brine is pumped through the outer jacket to hold the cider at about 28° F. When the cider is thoroughly cooled it is circulated by means of a juice pump to enable a greater absorption of carbon dioxide.

Counter-Pressure Bottling.—Usually the cider is ready for bottling after two days in the cooling tank. Hence the Seitz filter is previously built up with asbestos sterilizing discs and connected with the bottling machine. This line-up is sterilized with live steam at 10 lbs. for 45 minutes and cooled by passing cold water through the set-up. The filter is then connected to the bottom valve of the tank and the gas outlet on the bottler is joined through an air filter to the top valve. The valves are then opened with alternate differentials of 10 pounds pressure per sq. in. until the pressure has become equalized throughout. The cider is pumped through the filter into the reservoir of the bottling machine from which the bottles are filled. Each spout on the bottling machine, which is the champagne type, has a double valve which when partly opened fills the bottles with compressed CO_2 and when fully opened permits the cider to enter the bottles under counter-pressure thus preventing foaming.

Naturally, as the cider is bottled the pressure in the line-up would drop. To offset this a cylinder of compressed CO_2 is connected in the gas line with a pressure-control valve attached to keep the pressure constant during the bottling operation.

As the bottles are filled they are placed on a revolving counter-pressure table which holds the open ends tight against a rubber plug to allow any foaming to subside without losing the contents of the bottles. The bottles are then removed and capped or corked ready for storage.

Similar Methods

Other methods are used which differ somewhat from the Closed Cuvee Process. One of these is to do away with the fermenting tank and carbonate artificially while bottling. However, the natural aroma and bouquet retained by natural carbonation is often lost if artificial carbonation is resorted to.

Pasteurization has been tried to obviate the use of the Seitz sterilizing filter but many people complain that cider pasteurized in bottles has a cooked flavour.

Storage

Bottled cider should be stored in a cool, airy room. A temperature of about 40° F. is satisfactory since the greatest flavour is experienced when served at this temperature. Also, the bottles should be stored on their sides thus keeping the stoppers wet and preventing the escape of CO_2 through dry stoppers.

Controlled Variation of Cider

One of the advantages which cider has over other beverages is that it can be made to suit several tastes. For those who cannot or will not drink an alcoholic beverage a sweet cider can be made either still or carbonated.

This is a very popular drink throughout eastern Canada and the United States.

Then for those who prefer some stimulant in their beverage a medium cider containing up to 7% alcohol is suitable. Where an even stronger and finer beverage is wished a champagne cider is available containing 10 to 12% of alcohol. This ability to vary the alcoholic content of the cider to suit varying tastes should be a strong attraction to the producer.

Cider Troubles

Lest any should think that cider-making is simple and easy to master, some of the difficulties involved should be mentioned. Trouble may suddenly appear without apparent reason, but since there usually is a reason for everything, we try to find what it is and how to control or avoid the trouble.

(a) Arrested Fermentation.—A batch of cider inoculated with a vigorous yeast culture may not ferment, or fermentation may proceed for a short time then gradually stop. Sometimes, as suggested before, it may be due to insufficient heat since most yeasts have an optimum temperature of 75° to 85° F.

Another reason sometimes encountered is insufficient yeast food. During processing, centrifuging and filtering remove large amounts of suspended material and fining carries down so much food that when inoculated the yeast cells may be starved. In such cases the addition of small amounts of such compounds as ammonium sulphate, ammonium phosphate or potassium phosphate will enable fermentation to proceed.

(b) Blackening and Greening.—Another trouble sometimes encountered is a complete blackening of the cider, usually on exposure to air. This is usually accompanied by a decrease in the acidity. There may be several reasons for this trouble; one is that an acid-destroying bacteria is responsible. We have isolated several organisms one of which apparently causes some darkening but does not alter the acidity. Another possible cause is an excess of calcium, perhaps resulting from reduction of acidity with calcium carbonate, but up to the present we have no definite results to prove this point.

Metallic contamination is a likely possibility. Iron does turn cider black, evidently due to the formation of iron tannates. However, it has been found that iron will also gradually blacken a solution of malic acid which is the chief acid in apples. Usually, where blackening is accompanied with a decreased acidity the addition of a fruit acid such as malic, citric or tartaric acid will restore the cider to its normal colour.

The appearance of a green colour in the cider is occasionally encountered and is probably due to copper contamination. Thus the importance of avoiding metallic contamination cannot be stressed too much. Apart from the effect on colour, such contamination will stop fermentation. The cure for such a trouble is one of prevention. All metal parts with which the cider comes in contact should be silver plated or tinned.

Sedimentation.—Occasionally cider which has been bottled sparkling clear may develop a cloudiness or throw a sediment. The presence of pectin is sometimes responsible evidently becoming insoluble and settling out.

Residual chlorine remaining in the bottles after sterilizing with chlorine solution will cause sedimentation. As little as 0.6 ppm. of chlorine has been found to cause the formation of sediment.

Casse.—The appearance of "casse" or "break" in bottled cider may render the appearance slightly unattractive. The "casse" usually takes the form of breaking down of some constituents resulting in a peculiar sediment. A good preventive is the addition of sulphur dioxide which inhibits the action of peroxidase, the enzyme which is apparently responsible.

Lack of Sterility.—If the cider is not sterile in the bottle, trouble is likely to develop. True, moulds will not grow in the highly carbonated liquid. But yeasts and certain forms of bacteria will cause a sedimentation which although not objectionable in Europe is nevertheless to be avoided here.

The bottles should receive a thorough washing in hot caustic soda, full rinsing in clear water and a complete rinsing with sodium hypochlorite testing about 1000 ppm. of free chlorine; this will give sterility. To avoid the sedimentation due to chlorine, experiments are being carried out for the removal of residual chlorine from the bottles without endangering sterility.

SUMMARY

The possibility of converting low grade apples into cider is discussed showing how the grower will benefit not only from the sale of such apples but also by removing them from competition with higher quality fruit. After showing briefly how cider production has developed in England and the development of cider varieties, the author points out that such varieties need not be developed here because many of our common apples when blended properly with juices of some crabapple varieties make an excellently flavoured beverage. A short description of various methods of cider making is given with a more detailed account of the Closed Cuvee Process as developed at the Fruit Products Laboratory, Central Experimental Farm, Ottawa. In conclusion the author discusses such troubles as arrested fermentation, blackening and greening, sedimentation, "casse" and lack of sterility.

Résumé

Le cidre, un produit des fruits. Wm. Ferguson, Ferme expérimentale centrale, Ottawa, Ont.

L'auteur traite de la possibilité de convertir en cidre des pommes de qualité inférieure. Il montre qu'il y a avantage pour le producteur à utiliser les pommes de cette façon, plutôt que d'essayer de les vendre en concurrence avec des fruits de qualité supérieure. Après avoir relaté sommairement comment la production du cidre s'est développée en Angleterre et comment les variétés à cidre ont été créées, l'auteur fait remarquer qu'il serait inutile de développer ici des variétés de ce genre parce qu'un grand nombre de nos pommes communes, mélangées dans la proportion voulue avec le jus de quelques variétés de pommettes, font un breuvage à goût exquis. Il donne une description sommaire des différents procédés de fabrication de cidre avec un compte rendu détaillé du procédé de "cuve close", développé au laboratoire des produits fruitiers, Ferme expérimentale centrale, Ottawa. En terminant, l'auteur traite de certains désordres comme l'arrêt de la fermentation, le noircissement et le verdissement, la sédimentation, la "casse" et le manque de stérilité.

TWO NEW METHODS OF DISTINGUISHING CERTAIN CANADIAN WHEATS

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For some time, it has been the aim of the plant breeder and plant systematist to obtain additional methods of identifying the numerous commonly grown wheat varieties. The positive identification of the Hard Red Spring Wheats of the same species by means of the kernel characters has not always been completely satisfactory.

The need of such a verification system is quite obvious in both the seed and grain trade. Those who have to distinguish between such varieties as Marquis, Reward and Garnet find the present cultural methods take either too long or do not provide a satisfactory clear cut identification.

Harrington (*4*) published an article on "Seedling Identification of Some Canadian Spring Wheats" with special emphasis on the Marquis, Reward and Garnet varieties. The differential seedling hairiness of Reward and Marquis wheats one day after emergence led to the successful separation of the two varieties. The test required about nine days to complete the identification of the varieties.

More recently, Friedberg (*2*, *3*) published detailed articles on the classification of wheats according to their colour reaction to phenol. The procedure for the phenol treatment is as follows:—

(*a*) *Spike Treatment.*—The spike with the kernels removed is soaked for 24 hours in a 1% phenol solution, then removed and dried.

(*b*) *Kernel treatment.*—The kernels are soaked for 16 hours in water, drained and let dry for 1 hour, then immersed in 5 cc. of a 1% phenol solution for 4 hours and dried on blotting paper. The colour is observed and recorded 4 hours after and again in 2 days after treatment.

METHODS AND MATERIAL

In the fall of 1934, the Cereal Division conducted a number of experiments in order to determine the reliability of the phenol colour test on some of the Canadian Hard Red Spring wheats in order to ascertain whether this means of identification was more accurate and faster than other existing methods. The experiments were planned from the standpoints of the plant breeder, seed merchant and grain trader. Since the plant breeder and seedsmen are both interested in the purity of single lines and the later seed populations, the method of approach to the experiment remained the same.

For the purpose of determining the purity, kernels from several varieties grown at different Experimental Stations scattered throughout Canada and from different crop years were used. The phenol gave distinct colour reactions of light and dark brown.

[1] Chief Assistant, Cereal Division, and Graduate Student respectively.

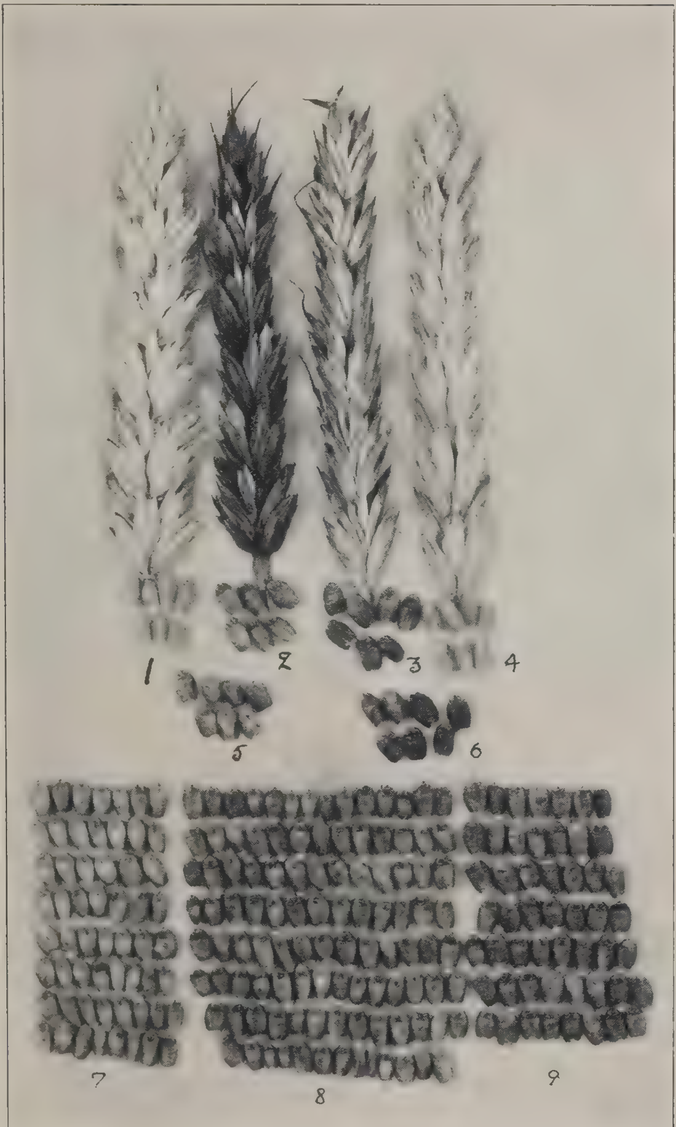


FIGURE 1. Phenol colour reactions with spikes and kernels
1. Red Fife Ott. 17 untreated; 2. Red Fife Ott. 17 treated with Phenol; 3. Garnet Ott. 652 treated with Phenol; 4. Garnet Ott. 652 untreated; 5. F_1 of Red Fife × Garnet cross treated; 6. F_1 reciprocal; 7. F_2 Red Fife parent colour reaction; 8. F_2 Intermediate parent colour reaction; 9. Garnet parent colour reaction.

The group of wheat varieties giving the dark and light brown colour reaction on the kernels were as follows:—

Light Brown Reaction

Red Bobs 222	C.A.N. 1637
Supreme	C.A.N. 1543
Early Triumph	C.A.N. 1291
Ruby Ott. 623	C.A.N. 1511
Parker's Sel.	C.A.N. 1460
Red Fife Ott. 17	C.A.N. 1515

Dark Brown Reaction

Marquis Ott. 15	C.A.N. 1396
Reward Ott. 928	C.A.N. 1509
Garnet Ott. 652	C.A.N. 1316
Ceres	C.A.N. 1263
Huron Ott. 3	C.A.N. 1344

All the spikes of the above varieties turned *brown* in phenol with the exception of the Garnet which remained *white*.

While testing Supreme wheat from various Stations, it was found that, although the spikes appeared morphologically alike, the kernels from one place gave dark brown reactions. This is a typical example of where the phenol test could be usefully employed to bring out differences amongst otherwise morphologically similar varieties.

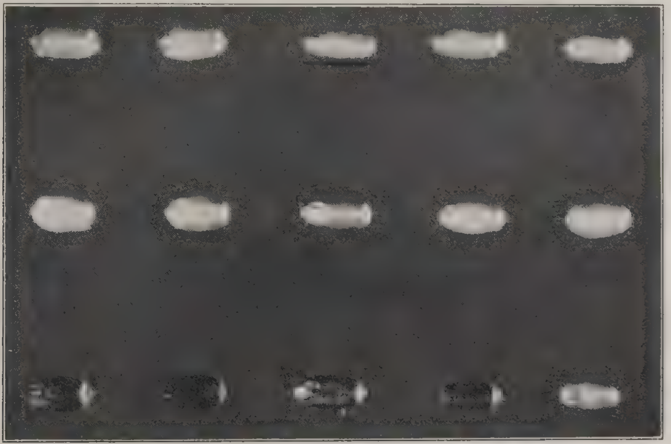
Another valuable application of the phenol test is illustrated in Figure 1 where the F_2 kernels of a Red Fife $\times$ Garnet cross gives a distinctive colour reaction from the range found in the parents. It would appear, therefore, that a phenol heterozygous reaction is indicative of hybridization or impurity.

In order to make a practical application which might be helpful to the grain trade in identifying varieties in bulk shipments, representative samples of wheat from the crop year of 1933 were taken from officially gathered overseas shipments and given the standard phenol treatment already outlined. The actual composition of these samples was known from the growing tests conducted in 1934. It is fully realized, at this time, that the phenol test is not in itself infallible, but when considered in conjunction with other kernel characters is a valuable additional aid in identifying the varieties mentioned above. Indeed, the greatest difficulty encountered in testing the reliability of the phenol tests was the differential found in the maturity of the varieties tested. This resulted in a miscellaneous colour reaction for the same variety. The fact that immature kernels did not produce a true varietal colour reaction was ascertained through testing an immature sample of Garnet and Reward wheat which were obtained from the Branch Sub-Station at Fort Smith, Northwest Territories.

Continued efforts to accentuate known characters in order to observe differences between varieties resulted in the successful differentiation of Garnet wheat from all other commonly grown Canadian wheats. This differentiation was accomplished by soaking wheat kernels of the varieties Marquis, Garnet and Reward in water for approximately 16 hours when the outline of the swelling germ could be distinctly observed. From the observation made at Ottawa, Garnet wheat was shown to have its germ

set into the body of the kernel at a more acute angle than any of the other common wheats usually associated with it in the trade in Canada, namely, Marquis, Reward, Ceres and Early Triumph. When viewed from above, one can see that the knob of the germ is midwide, somewhat pointed at the base and conspicuously protruding at the apex.

The way the germ is inset, general shape of the soaked seeds, along with the phenol colour reaction are presented in Figure 2. The obliqueness of the Garnet germ in comparison to the other varieties is quite noticeable.



Marquis	Reward	Garnet	Ceres	Early Triumph
Ott. 15	Ott. 928	Ott. 652		(..............)
(.......... Dark Brown Colour Reaction			..........)	Light Brown Colour Reaction

Varieties from left to right.

FIGURE 2. The two upper rows of kernels show the accentuated germ characters of five wheat varieties; Lower row of kernels indicates their phenol reactions. Note the acute slope of the Garnet germ.

From Table 1, it seems quite apparent that the length of germ has a tendency to increase with the depth of kernel, and that in Ottawa the germ and kernel size is greater than for the other Stations. The germ length and depth of kernel are undoubtedly more influenced by environment than the variability within the variety. This fact is well brought out in Table 2 where the standard error of the mean of the average measurements is approximately 10 times greater and remains fairly uniform for all varieties.

In Table 2, the measurements of 20 kernels of each of the 5 varieties, Marquis, Reward, Ceres, Garnet and Early Triumph are given as taken from wheat samples grown at the following Experimental Stations: Ottawa, Indian Head, Scott, and Swift Current. The kernels were picked at random from fairly uniform samples that were shipped to Ottawa for milling and baking experiments. From the standard error of the means for these Stations, it can be concluded that there was a small variability in the kernel depth and the germ length of these varieties. The depth of

TABLE 1.—AVERAGE MEASUREMENTS AND STANDARD ERROR IN MILLIMETERS OF THE DEPTH OF KERNELS AND LENGTH OF GERMS OF FIVE VARIETIES AT FOUR STATIONS DURING THE SEASON OF 1934

Variety	Ottawa		Indian Head		Scott		Swift Current	
	*Kernel depth in mm.	*Germ length in mm.	Kernel depth in mm.	Germ length in mm.	Kernel depth in mm.	Germ length in mm.	Kernel depth in mm.	Germ length in mm.
Garnet Ott. 652	2.77 ± .0054	2.70 ± .0059	2.53 ± .0053	2.40 ± .0045	2.55 ± .0064	2.49 ± .0050	2.34 ± .0050	2.44 ± .0043
Early Triumph	3.10 ± .0047	2.49 ± .0047	2.96 ± .0052	2.35 ± .0042	2.66 ± .0060	2.26 ± .0064	2.64 ± .0068	2.23 ± .0075
Ceres	3.11 ± .0065	2.52 ± .0061	3.06 ± .0026	2.26 ± .0038	2.82 ± .0061	2.24 ± .0043	2.87 ± .0064	2.22 ± .0045
Reward Ott. 928	3.14 ± .0038	2.42 ± .0056	3.02 ± .0034	2.24 ± .0038	2.73 ± .0051	2.24 ± .0048	2.77 ± .0064	2.20 ± 0033
Marquis Ott. 15	3.04 ± .0026	2.35 ± .0064	2.99 ± .0034	2.14 ± .0046	2.78 ± .0058	2.07 ± .0041	2.69 ± .0041	2.10 ± .0045

*The depth of the kernels and length of the germs were measured after soaking the entire kernel in water for 16 hours.

the kernel was taken immediately behind the germ and includes the portion from the apex to the cheeks of the kernel. Each seed was measured after receiving a uniform soaking for sixteen hours. The reason of the greater slope of the Garnet wheat germ by which it can readily be identified from the more common Canadian Hard Red Spring wheats is well presented in Table 2, where the depth of the kernel is almost equal to the length of the germ. It is for this latter reason that the Garnet germ assumes a greater slope.

TABLE 2.—MEAN OF AVERAGE MEASUREMENTS AND STANDARD ERROR IN MILLIMETRES OF THE DEPTH OF KERNELS AND LENGTH OF GERMS OF FIVE VARIETIES GROWN AT FOUR STATIONS DURING THE SEASON OF 1934

Variety	*Depth of kernel in mm.	*Length of germ in mm.
Garnet Ott. 652	2.54 ± .078	2.50 ± .060
Early Triumph	2.84 ± .084	2.33 ± .067
Ceres	2.96 ± .070	2.31 ± .060
Reward Ott. 928	2.88 ± .068	2.22 ± .052
Marquis Ott. 15	2.87 ± .063	2.14 ± .063

*The depth of the kernels and length of the germs were measured after soaking the entire kernel in water for 16 hours.

In Table 3, the measures of significance between means of paired values are presented. Again, it is observed that there is no significant difference between the depth of the Garnet kernels and the length of the germ for the four Stations. Early Triumph is the second longest in length of germ, but, in this case, the significance between the paired means of depth of kernel and length of germ is quite apparent. By pairing the means of the germ length of Marquis and Garnet wheat, the former having the shortest and the latter the longest germ, a very significant difference

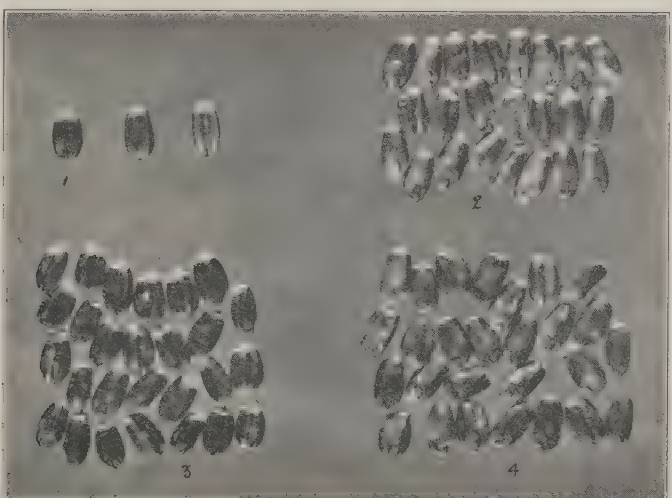


FIGURE 3. Accentuated brush characters of three prominent spring wheat varieties: Marquis Ott. 15, Reward Ott. 928 and Garnet Ott. 652. 1. Single specimens of Marquis, Reward and Garnet; 2. Garnet; 3. Marquis; 4. Reward.

TABLE 3.—THE t TEST OF SIGNIFICANCE BETWEEN THE MEANS IN MM. OF FOUR STATIONS OF THOSE VARIETIES THAT WERE CLOSEST IN THEIR MEASUREMENTS

Characters compared	t	P
(a) Garnet depth vs. length of germ	2.073	0.2 to 0.1
Early Triumph depth vs. length of germ	8.348	Less than 0.01
(b) Garnet germ vs. Marquis germ	9.970	Less than 0.01
Garnet germ vs. E. Triumph germ	4.216	0.05 to 0.02

is observed. The significant level drops slightly in comparing the germ length of Garnet with that of Early Triumph.

In Figure 3 the brush character is accentuated due to the phenol colouration. The silvery brush of the Marquis wheat, extending from the darkened kernel is a very pronounced characteristic, and the lack of the same in Reward wheat helps to differentiate these two varieties.

SUMMARY

1. An account has been given of the phenol colour reaction of kernels of wheat which were divisible into light and dark brown colour groups. The light brown colour reaction was obtained with Red Bobs 222, Supreme, Early Triumph, Ruby Ott. 623, Parker's Selection and Red Fife Ott. 17, while a dark brown colour reaction was given in the case of Marquis Ott. 15, Reward Ott. 928, Garnet Ott. 623, Ceres and Huron Ott. 3.

2. All the spikes of the above varieties coloured brown with the exception of Garnet which remained white.

3. Immature samples of wheat did not produce the same degree of colour as a fully mature sample.

4. The lengths of the germs and the depths of the kernels of seeds soaked in water for 16 hours were presented for the following varieties: Garnet Ott. 652, Marquis Ott. 15, Reward Ott. 928, Ceres and Early Triumph. The mean measurement of each variety was based on 80 kernels of which 20 were picked at random from samples grown at Ottawa, Indian Head, Scott and Swift Current.

5. Environment contributes more to the variability of the length of germ and depth of kernel than the differences within a variety in a district.

6. Garnet wheat was readily distinguished by its acute germ inset. This fact was again brought out by its mean of average kernel depth in mm. of $2.54 \pm .078$ and its mean germ length in mm. of $2.50 \pm .060$ There was no significant difference between the above two measurements where P is .2 to .1.

7. The Early Triumph kernel approached Garnet closest in germ length and kernel depth, but the difference between the compared means was significant because P is less than .01.

8. In pairing the mean values of Garnet germ vs. Marquis germ (*e.g.* long vs. short) the significance was considerable for P = less than .01 The significant level was lowered to give a P value between .05 to .02

when comparing the Garnet long germ vs. the Early Triumph mid-long germ.

9. The systematic value of the length of germ and depth of kernel was a striking example with the Garnet wheat kernels.

10. It was also evident that the phenol colour reaction accentuates the well known brush characters, and was a valuable means of separating Marquis wheat from a mixture of Garnet and Reward.

11. The data contained in this paper present to the plant breeder additional ways of establishing the genetic composition of hybrids, indentification of pure lines and classification.

12. In commerce, a system of this kind may be used to advantage for the verification of seed samples, the elimination of synonyms among commercial varieties and grading of export samples.

ACKNOWLEDGMENTS

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Résumé

Deux nouveaux moyens de distinguer certains blés canadiens. J. G. C. Fraser et F. Gfeller, Ferme expérimentale centrale, Ottawa, Ont.

La réaction de couleur donnée par les grains de blé traités au phénol est le sujet de cette étude. Ces grains se divisaient en deux groupes, à couleur brun clair et à couleur brun foncé. La réaction brun clair a été obtenue sur les Rouge de Bobs 222, Suprême, Triomphe Hâtif, Rubis, Ott. 652, Sélection de Parker et Fife Rouge Ott. 17 tandis que les Marquis Ott. 15, Reward Ott. 928, Garnet Ott. 652, Cérès et Huron Ott. 3 donnaient une réaction brun foncé. Tous les épis des variétés qui précèdent se sont colorés en brun à l'exception du Garnet qui est resté blanc. Les échantillons de blé non mûrs n'ont pas produit le même degré de couleur qu'un échantillon complètement mûr. La longueur des germes et la profondeur des grains de blé trempés dans l'eau pendant 16 heures sont présentées pour les variétés suivantes: Garnet Ott. 652, Marquis Ott. 15, Reward Ott. 928, Cérès et Triomphe Hâtif. La mesure moyenne, pour chaque variété, est basée sur 80 grains, dont 20 ont été pris au hasard sur des échantillons produits à Ottawa, Indian Head, Scott et Swift Current. La longueur du germe et la profondeur du grain varient suivant les conditions environnantes, qui paraissent être un facteur plus important sous ce rapport que les différences présentées par une variété. Le blé Garnet se distinguait facilement par son germe saillant, faisant encore ressortir la profondeur moyenne du grain qui était en mm. de 2.54 .078 et la longueur moyenne du germe, en mm. 2.50 0.060. Il n'y avait aucune différence significative entre les deux mesures qui précèdent lorsque P est .2 à .1. Le grain du Early Triumph est celui qui se rapprochait le plus de celui du Garnet au point de vue de la longueur du germe et de la profondeur du grain, mais la différence entre les moyennes comparées était significative parce que P n'atteint pas .01. Une comparaison des valeurs moyennes du germe du Garnet et du germe du Marquis (long contre court) révèle une différence considérable, savoir P = moins que .01. Le niveau significatif a été abaissé pour donner une valeur P entre .05 et .02 en comparant le long germe du Garnet au germe de longueur intermédiaire du Early Triumph. La valeur systématique de la longueur du germe et de la profondeur du grain est un exemple frappant en ce qui concerne les grains du blé Garnet. Il est évident également que la réaction de couleur au phénol accentue les caractères de brosse bien connus et que c'est là un moyen utile de séparer le blé Marquis d'un mélange de Garnet et de Reward. Les données contenues dans ce travail offrent au sélectionneur de plantes de nouveaux moyens d'établir la composition génétique des hybrides, l'identification des lignes pures et la classification. Un système de ce genre pourrait être employé avantageusement dans le commerce pour la vérification des échantillons de semence, l'élimination des synonymes parmi les variétés commerciales et le classement des échantillons d'exportation.

TIME OF HEADING AND FLOWERING OF EARLY, MEDIUM, AND LATE TIMOTHY PLANTS AT DIFFERENT LATITUDES

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INTRODUCTION

The relation between the time of flowering and the seasonal conditions at different latitudes, or of any other biological phenomenon, is a complex one. According to Hopkins' Bioclimatic Law (*5*), if other conditions, such as those relating to longitude, altitude, distance to large bodies of water, and other factors which may have an effect on local climates are equal, then the time of flowering, or any other periodical event in the spring, should progress from south to north, in the northern hemisphere, over the entire range of latitude where any species of plant under consideration may grow, at the uniform rate of one fourth of a degree of latitude each day.

In 1920, two years after Hopkins' Bioclimatic Law had been published, Garner and Allard (*4*) described the results of a study which they had conducted on the effects of different lengths of day upon the growth of plants of different kinds. They found that some plants do not produce inflorescences unless they are growing under days exceeding some minimum length—which varies for different species and varieties; plants of this kind are called long-day plants. Other plants produce inflorescences only when the length of day is reduced so that it does not exceed some certain maximum length; they are known as short-day plants. Still another group of plants seem more or less indifferent to length of day. Reproductive processes, in this type, are less dependent upon the season than in the other two groups.

Timothy *(Phleum pratense)* has the characteristics of a long-day plant. If timothy plants are transplanted to a greenhouse early in the winter, and are grown there with normal illumination, even though soil and temperature conditions are favourable for vigorous growth, the stems do not become elongated to form culms until spring. The formation of inflorescences is delayed until nearly as late in the spring as on plants which have been out of doors, in a more or less dormant condition, during the entire winter. If at any time during the winter, however, the length of day is artificially extended from sundown to about midnight by means of a 200-watt ordinary electric light bulb suspended over the timothy plant in the greenhouse, the stems begin to grow in length. Within a few weeks inflorescences appear, and a little later the florets bloom in the same way as on timothy plants in meadows during late spring and early summer (*1*, p. 45–49).

Plants of two of the strains of timothy, numbers 11902 and 12421, used in this investigation also were grown in 1928 and 1929 in an earlier experiment, at six stations, ranging from Savannah, Georgia, at 32 degrees

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6 minutes, to Fairbanks, Alaska, at 64 degrees 51 minutes north latitude. The time when the first florets bloomed progressed from south to north, not at a uniform rate, but at a rate which was constantly accelerated as the season advanced. This effect was attributed to the greater lengths of day occurring during late spring and early summer, at northern than at southern latitudes (*2*).

Progress of the Season for Heading and Flowering of Early, Medium and Late Strains of Timothy

In the experiment to which reference has been made, the progress of the season of the later strain, 12421, differed somewhat from that of the earlier strain, 11902. This fact indicated the desirability of conducting further investigations of the way in which the season for the appearance of the inflorescences, or heads, and the beginning of the flowering process, progresses from one latitude to another. Accordingly, 13 strains of timothy which range, with fairly uniform gradations, from very early to very late were grown in 1933 at three stations at different latitudes. The locations of these stations are as follows:—

—	Latitude		Longitude		Altitude feet
	Degrees	Minutes	Degrees	Minutes	
Washington, D.C., U.S.A.	38	54	77	3	50
North Ridgeville, Ohio, U.S.A.	41	23	82	2	750*
Guelph, Ontario, Canada	43	33	80	16	1120

*Approximate.

TABLE 1.—DATES WHEN THE TIP OF THE FIRST INFLORESCENCE, EMERGED FROM THE LEAF SHEATHS WITHIN WHICH IT HAD DEVELOPED, ON THE TIMOTHY PLANTS GROWN AT STATIONS AT 3 DIFFERENT LATITUDES. (IN 1933.)

F.C. number	Washington, D.C.	North Ridgeville, Ohio	Guelph, Ontario
19456	May 13	May 22	June 3
19458	May 17	May 25	June 2
15092	May 23		June 4
11902	May 24	May 29	June 8
6127	June 2	June 3	June 8
6743	May 31	June 7	June 11
9220	June 10	June 10	June 12
12421	June 14	June 20	June 20
15485	June 23	June 21	June 25
19416	June 23	June 25	June 24
15445	July 1	June 28	June 24
19459	July 10	July 3	June 26
19460	July 16	July 9	June 30

The plants of each strain had been propagated vegetatively from the same original plant, so there were no genetical differences among them, as would have been the case if they had been grown from seed. The plants were transplanted to the locations where they were grown in 1932, so that all plants had become well established when growth began in the Spring of 1933.

The strains of timothy used were F.C. selection numbers,[4] developed at the Timothy Breeding Station which is conducted co-

[4] A series of numbers used by the Division of Forage Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture.

operatively at North Ridgeville, Ohio, by the Division of Forage Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture, and the Department of Agronomy of the Ohio Agricultural Experiment Station. Records were obtained of the date when the tip of the first head on each plant emerged from within the leaf sheaths in which it had been enclosed, and of the date when the first florets bloomed on each plant. Observations and notes were also made to show whether the stems of the plants were upright in their habit of growth, or whether they were more or less declined at the base.

TABLE 2.—DATES WHEN THE FIRST FLORETS BLOOMED ON TIMOTHY PLANTS GROWN AT STATIONS AT 3 DIFFERENT LATITUDES. (IN 1933)

F.C. number	Washington, D.C.	North Ridgeville, Ohio	Guelph, Ontario
19456	May 27	June 5	June 20
19458	June 2	June 8	June 20
15092	June 6	June 10	June 22
11902	June 8	June 12	June 25
6127	June 13	June 16	June 25
6743	June 14	June 22	June 28
9220	June 23	June 27	June 28
12421	June 28	June 29	July 3
15485	July 3	July 4	July 8
19416	July 10	July 5	July 6
15445	July 13	July 10	July 7
19459	July 25	July 15	July 8
19460	July 31	July 22	July 15

Early, Medium and Late Strains of Timothy Respond Differently to Conditions at Different Latitudes

The dates when the tip of the first head appeared on each plant, at each one of the three stations, is shown in Table 1, and similar information in regard to the time of flowering is shown in Table 2. The dates when florets began to bloom is also presented, in graphical form, in Figure 1.

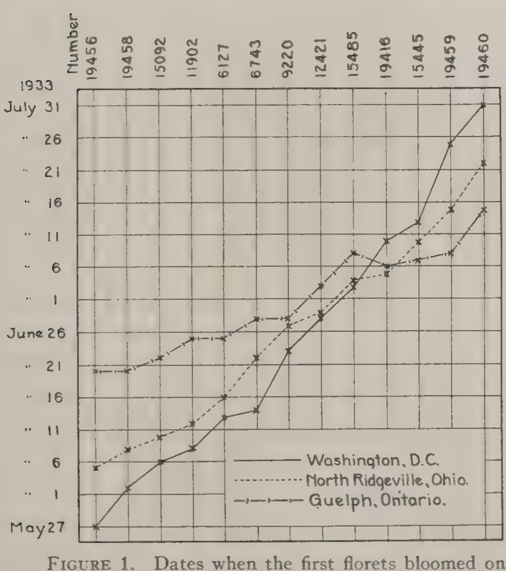

FIGURE 1. Dates when the first florets bloomed on timothy plants propagated vegetatively from the original plants of the selections indicated. These plants were grown at Washington, D.C., and at North Ridgeville, Ohio, U.S.A., and at Guelph, Ontario, Canada, with normal illumination. (In 1933.)

The records which have been presented show that the florets of the plants of the earliest timothy selection, 19456, bloomed at Washington 24 days before they did at the most northern station at Guelph. The other selections which are earlier than medium bloomed first at Washington, then at North Ridgeville, and finally at Guelph, though the differences in time of blooming at the three latitudes

was gradually less, as the selections rank later in the series. The time of flowering of some of those selections which rank about midway, and a little later, in the series, was approximately the same at all three stations. In the case of the 3 latest selections, the progress of the season for heading and blooming was reversed, occurring first at the northern station, then at the one midway between the others, and finally at the southern station. The florets of the plants of the latest selection, 19460, bloomed at Washington 16 days after they did at Guelph, more than 4.5 degrees further north.

In a general way, the statements which have been made in regard to the time of flowering of these timothy plants at 3 different latitudes also apply to the dates on which the tips of the first heads appeared on these plants.

Comparison of the Results with those Predicted by Hopkins' Bioclimatic Law

According to Hopkins' Bioclimatic Law, if other conditions are equal, the season for any periodical biological event, progresses in the spring from south to north at the uniform rate of one-fourth of a degree per day. Since Guelph is slightly more than 4.5 degrees north of Washington, if this law were equally applicable to these timothy selections, they should have all headed and bloomed at Guelph about 18 days after they did at Washington. As has already been stated, the earliest selection bloomed 24 days later at Guelph. The next to the earliest selection, 19458, did bloom as predicted exactly 18 days later at Guelph than at Washington. The two next earliest selections bloomed 16 or 17 days later at Guelph than at Washington; the slight deviations from the 18 days predicted possibly may be accounted for by differences in longitude, altitude, distance from large bodies of water or other local conditions recognized in Hopkins' Bioclimatic Law as factors which affect the progress of the season. There is no statement in this law, however, suggesting why the season for heading and flowering of the 3 latest selections should progress from north to south.

Time of Heading and Flowering in Relation to the Lengths of Day Occurring at Different Latitudes

What hypothesis may be offered for the different ways in which the season for heading and blooming of the early, medium, and late strains of timothy progressed?

In an experiment conducted in 1931 by Evans and Allard (*3*), most of the same selections which were used in this investigation were grown under days, artificially made of different uniform lengths, *i.e.*, 10.0, 12.0, 12.5, 13.0, 13.5, 14.0, 14.5, 15.0, 16.0, 17.0 and 18.0 hours. Plants of each strain were grown under part or all lengths of day. The early, medium, and late strains of timothy responded differently; a difference of half an hour, near the critical length of day under which development of stems and inflorescences formed, had a profound effect upon the growth of the plants.

With 10.0 hours light each day, plants of only the earliest selection, 19456, produced culms and inflorescences. With 12.5 hours of light, the next three earliest selections also produced inflorescences; under this length of day, all of those selections which are later, when growing under natural conditions, made only vegetative growth. When the plants of the later strains were grown under progressively longer days, those selections

which are increasingly later responded by producing culms and inflorescences. For the three latest selections from 14.5 to 15.0 hours of light were required for reproductive growth. In the case of all strains, the time required for the growth of culms and inflorescences became shorter, as the length of day increased from the minimum to the optimum for this development. If the length of day is near the minimum, the time when florets begin to bloom may be a month or more later than if the length of day is 3 or 4 hours above the minimum.

The length of day on any date during late spring or early summer, when plant growth is most active, varies at different latitudes. About June 21, when the maximum daily duration of possible sunshine occurs, the length of day, from sunrise to sunset, is as follows at the stations indicated:—[5]

Washington, D.C.	14 hours 55 minutes
North Ridgeville, Ohio	15 hours 8 minutes
Guelph, Ontario	15 hours 29 minutes

The early, medium, and late selections of timothy grown at different latitudes responded, in respect to the time heads appeared and florets began to bloom, in much the same way as they did to days of different uniform lengths in the earlier experiment. The length of any day during late spring and early summer gradually increases from south to north. The differences in day length at the three stations where this investigation was conducted seem to furnish the key to the explanation of the results which were obtained.

At the southern station, Washington, D.C., the temperature becomes high enough for plant growth to take place, several weeks earlier in the spring than at the northern station at Guelph, Ontario. The days are of sufficient length at Washington compartively early in the spring for the development of inflorescences of the earliest selection, 19456, consequently florets began to bloom 24 days earlier than at Guelph, where temperature was the limiting factor. In the case of the latest selections, however, which require relatively long days for the formation of inflorescences, length of day instead of temperature, was the limiting factor. Notwithstanding the favourable temperature during the spring, the development of inflorescences was delayed in these late selections until the season had advanced to a time when the days had become long enough for reproductive development. It may be attributed to the fact that this condition of day length was fulfilled at Guelph earlier than at North Ridgeville, and at North Ridgeville earlier than at Washington, that the season for heading and blooming, in the three latest strains of timothy used in this investigation, progressed from north to south, instead of from south to north.

In the earlier experiment, conducted in 1931, it was found that when timothy plants were grown under lengths of day which were near the minimum for the formation of inflorescences, the stems were more or less declined at the base, while other plants of the same strains, grown under favourable lengths of day, had upright stems. At each of the three stations where these timothy selections were grown in 1933, the stems of the three latest ones, 15445, 19459 and 19460, were much declined at the base. The

[5] Data supplied by the Weather Bureau, United States Department of Agriculture.

stems of 19416, the fourth from the latest selection, were declined at Washington, were slightly declined at the base at North Ridgeville, but grew upright at Guelph. The stems of the plants of all other selections, at all stations, were upright in their habit of growth. This result suggests that for the three latest selections, the lengths of day which occurred at all three stations were near the minimum under which reproductive growth occurs in these selections; while for the plants of timothy 19416, the lengths of day approach the optimum at Guelph, are somewhat below the optimum at North Ridgeville and even more so at Washington.

SUMMARY

A series of 13 strains of timothy ranging by fairly uniform gradations from very early to very late were grown at stations at three different latitudes, extending from Washington, D.C., at 38 degrees 54 minutes to Guelph, Ontario, Canada, at 43 degrees 33 minutes north latitude. The third station, North Ridgeville, Ohio, approximately midway between the other stations, is at latitude 41 degrees 23 minutes.

The florets of the earliest strain began to bloom at the southern station 24 days sooner than at the northern station. In selections progressively less early, the difference between the time of heading, or appearance of the inflorescence, and of blooming at the southern and the northern station gradually decreased. Those selections which are approximately medium between the earliest and latest in the series produced heads and the florets bloomed at nearly the same time at all three stations. The progress of the season for heading and blooming of the three latest strains of timothy was from north to south, instead of from south to north.

In very early strains heads develop and the flowering process occurs with days 10 to 12 hours long. In strains which are later under natural conditions, longer days are required for these processes, if the plants are grown under days artificially made of uniform lengths. At the southern station where this experiment was conducted, the lengths of day during late spring and early summer are not as great as at the stations further north. For the earliest strains, the lengths of day at the southern station are sufficient for the development of heads to begin before the temperature becomes high enough for active growth at the stations further north. In the case of very late strains of timothy, on the other hand, length of day apparently is the limiting factor at the latitudes where this experiment was conducted. Since the minimum length of day in the spring is attained, in the northern hemisphere at stations which are relatively far north, sooner than at stations further south, the season for heading and flowering of these very late strains of timothy consequently progresses, in the latitudes where this experiment was conducted, from north to south.

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Résumé

Epoque de l'épiage et de la floraison des plantes hâtives, intermédiaires et tardives de fléole (Mil) sous différentes latitudes. M. W. Evans et H. A. Allard, Ministère de l'agriculture des Etats-Unis, et O. McConkey, Collège d'agriculture de l'Ontario, Guelph, Ontario.

Une série de 13 espèces de fléole des prés (mil) variant par gradations assez uniformes depuis une espèce très hâtive jusqu'à une espèce très tardive, a été cultivée sous trois latitudes différentes, depuis Washington, D.C. à 38 degrés 54 minutes jusqu'à Guelph, Ontario, Canada, à 43 degrés 33 minutes latitude nord. La troisième station, North Ridgeville, Ohio, à peu près à mi-chemin entre les autres, est à 43 degrés 23 minutes de latitude. Les fleurons de l'espèce la plus hâtive ont commencé à fleurir à la station du sud 24 jours plus tôt qu'à la station du nord. Dans les sélections progressivement moins hâtives, la différence entre l'époque de l'épiage (ou l'apparition de l'inflorescence), et de la floraison, entre la station du sud et celle du nord, diminuait graduellement. Ces sélections, qui sont approximativement intermédiaires entre l'espèce la plus hâtive et l'espèce la plus tardive de la série, ont produit des épis et les fleurons ont fleuri à peu près à la même date sur toutes les trois stations. La marche de la saison pour l'épiage et la floraison des trois espèces les plus tardives de fléole allait du nord au sud, au lieu d'aller du sud au nord. Dans les espèces très hâtives, l'épiage et la floraison se produisaient lorsque le jour a une longueur de 10 à 12 heures. Chez les espèces qui sont plus tardives dans des conditions naturelles, des journées plus longues sont nécessaires pour ces procédés, lorsque les plantes sont cultivées dans des journées de longueur artificiellement uniforme. A la station du sud où cette expérience a été conduite, les jours de la fin du printemps et du commencement de l'été ne sont pas aussi longs qu'aux stations situées plus au nord. Pour les espèces les plus hâtives, la longueur des jours à la station du sud est suffisante pour que les épis commencent à se développer avant que la température se réchauffe suffisamment pour favoriser une végétation active aux stations situées plus au nord. Par contre, dans le cas des espèces très tardives de fléole, la longueur du jour parait être le facteur limitatif, aux latitudes où cette expérience a été conduite. Comme la longueur minimum du jour dans l'hémisphère du nord, au printemps, est atteinte plus tôt aux stations relativement loin dans le nord qu'aux stations plus au sud, la saison d'épiage et de floraison de ces espèces très tardives de fléole va donc en progressant du nord au sud, dans les latitudes où cette expérience a été conduite.

STUDIES IN INTERSPECIFIC CROSSING WITH *MELILOTUS* AND IN INTERGENERIC CROSSING WITH *MELILOTUS MEDICAGO* AND *TRIGONELLA*[1]

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The investigations discussed in this paper were carried out during the years 1931–34. The purpose of the work was fourfold; (*1*) to determine to what extent it may be possible to produce hybrids, by controlled crossing, between the more commonly grown species of sweet clover; (*2*) to learn something of the possibilities of intergeneric crossing between *Melilotus*, *Medicago* and *Trigonella;* (*3*) to study the behaviour of any hybrids which might result from these crosses with respect to their value in crop improvement; and (*4*) to endeavor to throw some light upon the origin of certain new plant types which have from time to time appeared in our sweet clover plots and which, we have reason to suspect, may have resulted from natural crosses in which common white blossom sweet clover was one of the parents.

Natural crosses between certain members of the *Melilotus* group have been observed in a few instances. Haussknecht (*5*) described hybrids which he believed to have resulted from the spontaneous crossing of *Melilotus albus* and *Melilotus officinalis.* These plants he observed to be intermediate between the two parents with respect to many characters. The flower colour is described as showing "a little yellowish tint which appears, if closely examined, like a dirty white". Their pollen grains were of abnormal shape and structure and they set little seed.

Kirk (*6*) obtained only one natural hybrid from 11,400 plants arising from seed harvested from a row plot of *M. albus* which was grown under conditions most favourable for natural crossing. Ten varieties or species of yellow blossom sweet clover surrounded the plot from which this seed was gathered. The F_1 hybrid possessed pale yellow flowers. Flowers of a "dull white" colour, showing only a slight yellowish tint, appeared in the F_2 progeny, Kirk (*7*).

Sylven (*11*) observed two plants, grown from a lot of seed imported from Canada, which he believed to be natural hybrids between *M. albus* and *M. officinalis.* These plants were intermediate between the parent species with respect to most characters. They produced flowers of a "pale yellow or yellowish white" colour. The pollen produced by them was from 50% to 80% sterile.

The possibility of producing interspecies hybrids in *Melilotus*, by means of artificial cross-pollination, appears to have received little attention. Kirk (*8*) made an extensive series of crosses between *M. albus* and *M. officinalis* and did not obtain a single hybrid therefrom. He observed that such cross-pollinations usually resulted in the formation of seeds

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but that the seeds so produced failed to develop normally. They were small, shrunken and non-viable.

Dann (*2*) attempted to produce hybrids between *Medicago* and *Melilotus*. When *Melilotus* was used as the female parent not a single seed was produced. A few poorly developed, non-viable seeds were obtained from the reciprocal cross.

DESCRIPTION OF MATERIAL

The material employed in these experiments consisted mainly of a number of varieties and selections which had been grown and observed for several years in our breeding nurseries and in addition a number of single plants grown from commercial seed. A brief description of the various varieties and selections follows:

Group I, *Melilotus albus* Desr., consisting of the following material: "Arctic" a semi-dwarf, hardy variety of Siberian origin, which is widely grown in Saskatchewan. Several lines which had been previously selected from Arctic and inbred for two or more generations were also used, mainly because of marked differences in flower structure. Four varieties of the dwarf branching or "Alpha" type and a number of individual plants grown from ordinary commercial seed were also included.

Group II, *Melilotus officinalis* (L) Desr., containing two of the more widely grown yellow blossom varieties, Albotrea and Zouave. The former variety is quite typical of this species. Zouave is distinct among the yellow blossom sorts in that it produces an upright growth in the seedling year. Both these varieties are non-self-pollinating. Plants grown from commercial seed were also available.

Group III, *Melilotus* sp., contains only one variety—Redfield Yellow. This is a very late flowering, leafy type which originated at Redfield, South Dakota. This variety is largely self-pollinating, a fact which may explain the unusual uniformity which it possesses. At various times this variety has been regarded as a member of the *M. officinalis* and *M. sauveolens* groups. Dr. Samuel Garver, Redfield, South Dakota, has the following to say regarding the botanical position of this variety: "We have not yet been able to identify this variety botanically. For a time we thought it was *M. sauveolens* but it does not entirely answer to the description of that species as given in the German Monographs on the genus . . . ". On the other hand Brink (*1*) states that it is doubtful whether Redfield Yellow belongs to *M. officinalis*.

Group IV, *Medicago media* Pers., contains a number of selections from each of several strains of the "Grimm" variety. The individual plants exhibit marked differences, especially with respect to seed setting.

Group V, *Trigonella coerulea* (L) Ser., consisted entirely of plants grown from commercial seed. This material possessed unusual uniformity.

EXPERIMENTAL METHODS

Most of the crossing work was carried out in a greenhouse from which insects, with the exception of aphids, were excluded by means of fine mesh wire screening. Aphids, which appear to be of little consequence in the transportation of pollen, were controlled by fumigation. Some crosses

were made also in the field nurseries in which cases either the entire plant was protected by a wire screen or a cotton cage or the crossed racemes were enclosed in glassine bags. Seed setting on field crosses was not significantly different from that obtained under greenhouse conditions. Plant material was grown in the greenhouse and crosses were made throughout the entire year, so that a wide range of conditions, with respect to length of day and to temperature, were experienced. In addition artificial light was used in some cases to hasten maturity. None of these conditions appeared to have markedly affected the seed setting.

Parent material was either grown from seed sown directly into pots in the greenhouse or was transplanted from the field nursery to pots and taken to the greenhouse.

Three methods of emasculation were practiced. The particular method to be used was decided upon after an examination of the flowers of the parent material. Sweet clover plants which possessed the non-self-pollinating flower structure, as described by Kirk and Stevenson (*9*), were easily and effectively emasculated by use of the suction method devised by Kirk (*8*) or by simply removing the petals from the fully open flowers and blowing the pollen off. This latter method, while slightly less certain than the suction method, is relatively rapid and was satisfactory on this type of plant. Self-pollinating types of sweet clover, also all alfalfa and *Trigonella* plants, were emasculated in the bud stage. Flowers which would be expected to open under normal conditions in from three to four days were selected. The procedure was to split the standard down the back thus exposing the anthers which were readily removed by means of a dissecting needle. A binocular magnifier ($\times 2$ or $\times 3$) with head attachment, so that the hands are left free, was found to be a most valuable aid in emasculation and pollination work.

Pollination was in all cases accomplished by gathering the pollen on the broad end of a toothpick and applying it directly to the stigmas of the emasculated flowers. When fully open flowers were emasculated they were pollinated immediately but those treated in the bud stage were not pollinated until the petals unfolded in the normal manner. This time varied from two to five days after emasculation.

In all cases when the flowers on a raceme were emasculated for crossing, those on another raceme of the same plant were emasculated at the same time. One of these racemes was pollinated and the other left unpollinated to serve as a control on the effectiveness of the emasculation. In addition several racemes were self-pollinated on each plant in order to observe the effect of selfing on seed setting and development.

The number of pods formed were recorded as soon as they appeared and their development from then on was closely observed. The seeds obtained from crossed flowers were carefully examined and a description recorded. They were then planted and the resulting plants, if any, were examined for hybrid characters. Crosses, as far as possible, were made in both directions.

EXPERIMENTAL RESULTS

I. Interspecific Crossing with Melilotus

Over 7000 crosses, involving a large number of parents, were made between *M. albus* and *M. officinalis*. When the white blossom plants

were pollinated with pollen from any of the *M. officinalis* parents, or when the reciprocal crosses were made, no hybrids resulted. Many of these crosses produced pods but most of these ceased development at an early stage (about 10 days after pollination). When the female parent was of the *M. albus* group they turned yellow and dropped off the plant in from 19-21 days. When the cross was made in the opposite direction they dropped from the plant in from 17-19 days after pollination. The seeds contained in these pods were always smaller than normal seeds and were shrunken and of a greenish brown colour. They failed to germinate in every case. The few pods which developed normally proved to have resulted from self-fertilization without exception. Some typical results from such crosses are presented in Table 1.

TABLE 1.—SOME TYPICAL RESULTS OBTAINED BY POLLINATING FLOWERS OF *M. albus* WITH POLLEN FROM *M. officinalis*

PARENTS Female × Male	No. of flowers cross-pollinated	Per cent of cross-pollinated flowers which produced viable embryos	Per cent of cross-pollinated flowers which produced abortive seed	Per cent of viable seed which produced hybrid plants	Per cent of viable seed which produced selfs
Arctic No. 1 × Albotrea	126	8	35	0	100
Arctic No. 2 × Albotrea	118	7	28	0	100
Arctic No. 3 × Albotrea	120	11	37	0	100
Arctic No. 4 × Albotrea	119	6	33	0	100
Arctic No. 5 × Albotrea	263	13	39	0	100
Alpha No. 1-42 × Albotrea	90	8	21	0	100
Alpha No. 3-82 × Albotrea	63	6	3	0	100
Arctic No. 1 × Zouave	144	5	45	0	100
Arctic No. 2 × Zouave	254	6	39	0	100
Arctic No. 3 × Zouave	120	11	37	0	100
Arctic No. 4 × Zouave	100	8	59	0	100
Arctic No. 5 × Zouave	85	7	38	0	100
Alpha No. 1-42 × Zouave	117	12	35	0	100
Alpha No. 3-82 × Zouave	140	0	0	0	100

NOTE: The percentages of viable seeds produced on these cross-pollinated flowers were not significantly different from those produced by the controls.

From more than 2700 crosses made by pollinating *M. albus* parents with Redfield Yellow pollen, or from the reciprocal crosses, very different results were obtained. Most of these crosses resulted in the formation of pods. From certain matings these were all normal; from others they were nearly all normal and from still others a high percentage were of the abortive type. In table 2 are presented data obtained from some of these crosses. The *M. albus* parents are the same ones that were used in the *M. albus* × *M. officinalis* crosses shown in Table 1.

From these data it may be noted that the production of viable seed was markedly higher than from the *M. albus* × *M. officinalis* crosses, shown in Table 1, while the percentage of crossed flowers which produced aborted seed were very much lower in most cases, and in two cases no seeds of this type were obtained. From several matings of Arctic × Redfield Yellow every viable seed produced hybrid plants even though the control racemes produced the usual percentage of selfed seeds. Since the

TABLE 2.—SOME TYPICAL RESULTS OBTAINED BY POLLINATING FLOWERS OF *M. albus* WITH POLLEN FROM REDFIELD YELLOW (*Melilotus* SP.)

PARENTS Female × Male	No. of flowers cross-pollinated	Per cent of cross-pollinated flowers which produced viable seed	Per cent of cross-pollinated flowers which produced abortive embryos	Per cent of viable seed which produced hybrid plants	Per cent of viable seed which produced selfs
Arctic No. 1 × Redfield Yellow	103	77	0	100	0
Arctic No. 2 × Redfield Yellow	106	57	10	100	0
Arctic No. 4 × Redfield Yellow	96	75	6	100	0
Arctic No. 5 × Redfield Yellow	138	87	0	100	0
Alpha No. 1-42 × Redfield Yellow	105	18	37	40	60
Alpha No. 3-82 × Redfield Yellow	318	14	20	66	34
Alpha No. 5-1 × Redfield Yellow	124	40	0	84	16

control flowers were emasculated at the same time and by the same method as the crossed flowers, we can only conclude that the Redfield Yellow pollen was able, for some reason, to effect fertilization even in competition with pollen produced by the female plant itself. From other matings, and notably from the Alpha × Redfield Yellow crosses, not only were abortive seeds obtained but a fairly large percentage of the normal seeds proved to have resulted from self-fertilization, indicating a less degree of compatibility than was shown with the Arctic female parents.

Not all of the matings, however, involving Arctic as one of the parents, were equal in this respect. Also there appeared to be as marked differences in the compatibility of various matings involving individuals from any one variety as there were between the matings involving the different varieties of *M. albus*. Likewise when any particular plant of *M. albus* was crossed with a number of different plants of Redfield Yellow, equally variable results were obtained.

It is therefore reasonable to assume, since hybrids were obtained readily from the *M. albus* × Redfield Yellow crosses, whereas efforts to cross *M. albus* with *M. officinalis* did not meet with success, that Redfield Yellow is distinct, genetically, from the other yellow flowered varieties or selections used in these crosses.

Further proof that Redfield Yellow is genetically distinct was evidenced by the results obtained from pollinating Redfield Yellow with

TABLE 3.—SOME TYPICAL RESULTS OBTAINED WHEN FLOWERS OF *M. officinalis* WERE POLLINATED WITH POLLEN FROM REDFIELD YELLOW AND WHEN THE RECIPROCAL CROSS WAS MADE

PARENTS Female × Male	No. of flowers cross-pollinated	Per cent of cross-pollinated flowers which produced viable seed	Per cent of cross-pollinated flowers which produced abortive embryos	Per cent of viable seed which produced hybrid plants	Per cent of viable seeds which produced selfs
Albotrea × Redfield Yellow	115	1	36	0	100
Zouave × Redfield Yellow	363	8	29	0	100
Redfield Yellow × Albotrea	117	7	42	0	100
Redfield Yellow × Zouave	107	6	16	0	100

pollen from Zouave and from Albotrea and from reciprocals of these crosses. From these matings no hybrids were produced. A number of abortive seeds resulted, however, as in the *M. albus* × *M. officinalis* crosses. In Table 3 are presented data from some of these crosses.

II. Intergeneric Crossing

Intergeneric crosses were made as follows:

Medicago × *Melilotus officinalis*	2084
Medicago × *Melilotus albus*	2990
Medicago × *Trigonella coerulea*	1003
Trigonella coerulea × *M. officinalis*	2035
Trigonella coerulea × *M. albus*	3460

The figures given include all cross-pollinations made between the species concerned irrespective of the direction of the cross.

When alfalfa flowers were pollinated with pollen from any of the varieties or species of either white blossom or yellow blossom sweet clover not a single seed was formed. From the reciprocal crosses, however, a few matings produced abortive seeds which behaved, in their development, similar to those obtained from the sweet clover species crosses. Approximately 75% of these reciprocal matings, however, failed to produce even abortive seeds. It is apparent that the type of incompatability present in most of these crosses was such that it prohibited fertilization.

When any of the yellow blossom sweet clovers were pollinated with pollen from *Trigonella coerulea*, or when the reciprocal crosses were made, not a single seed was formed. Crosses in which the white blossom sweet clovers were pollinated with pollen from *Trigonella coerulea*, however, produced seeds in many cases. Only a small percentage of these were of the abortive type. The percentage of normal seeds produced was greatly in excess of the seed setting obtained on the control racemes. These normal seeds, however, produced plants which, in all cases, closely resembled the maternal parent. Not a single one of them showed *Trigonella* characters. The consistency with which these results were obtained when the crosses were repeated indicated that they could not be explained on the basis of faulty emasculation. The possibility of apomictic development is being investigated. No seeds of any kind were obtained from the reciprocal crosses.

Crosses involving *Medicago* and *Trigonella* did not result in the production of a single seed irrespective of the direction in which the pollinations were made.

III. The Occurrence and Development of Abortive Embryos.

In the course of these and other experiments it was noted that the occurrence of abortive embryos in sweet clover was not peculiar to interspecific and intergeneric crosses only. Premature, shrunken, non-viable seeds resulted frequently from self-fertilized flowers of all of the various species and varieties worked with. Nor was this phenomena peculiar to plants grown under greenhouse conditions since similar seeds have been produced from field selfings.

The occurrence of these abortive embryos on self-fertilized plants was first observed in the inbred lines of *M. albus* and was particularly common in those of the non-self-pollinating type. Similar conditions were observed on several occasions, in self-fertilized flowers of *Medicago* and of *Trigonella coerulea*.

In the case of interspecific crosses involving the *M. albus* and *M. officinalis* groups a high percentage of the cross pollinated flowers (in one cross 59%) produced abortive embryos. Crosses between the same *M. albus* parents and Redfield Yellow, however, showed considerable variation in this respect. Certain inbred lines of Arctic, when crossed with Redfield Yellow, produced only normal seeds, all of which produced hybrid plants, while other lines produced a few seeds of the abortive type. Certain lines of Alpha, on the other hand, when crossed with Redfield Yellow, produced a fairly high percentage of abortive embryos.

The percentage of abortive embryos produced by these crosses did not appear to be influenced at all by the direction in which the crosses were made. The behaviour of the hybrid embryos produced on *M. officinalis* females, however, differed from those on the *M. albus* females in that the former dropped from the parent plants about two days earlier.

The writers are indebted to Dr. W. P. Thompson[4] for the following data regarding the fertilization and subsequent development of embryos from interspecific crosses involving the *M. albus* and *M. officinalis* groups. He observed that in all crosses pollen tube growth appeared to be normal. Fertilization occurred within twelve hours after pollination and practically all cross-pollinated flowers produced embryos. In Table 4 are presented comparative data relative to the development of these hybrid embryos.

TABLE 4.—COMPARATIVE DEVELOPMENT OF HYBRID AND SELFED EMBRYOS FROM ARCTIC × ZOUAVE CROSSES

Period of observation	Relative development	
	Hybrid embryo	Selfed embryo
First 7 days	Growth much like selfed sib but slower.	
At 7 day	Length 190-230 U.	Length 250-270 U.
At 10 day	Hybrid endosperms lag more strikingly than the embryos.	About 3 times as large as hybrids.
At 16-17 day	Outwardly appear normal but somewhat smaller than selfed sibs. The embryo-sac is a larger vacuole. The endosperm is not appreciably larger than at 10 days.	Endosperm and embryo fill the embryo-sac.
At 17-19 day	The embryo-sac collapses and the ovule appears shrunken.	
At 19-21 day	The ovule is discolored and appears dead. Embryo about 0.5 mm. long and is straight.	Ovule about 3.0 mm. long with large cotyledons and is curved.

[4] Unpublished data, Biology Department, University of Saskatchewan.

Hybrid embryos dissected out at an early stage and placed in sterile, nutrient media continued development considerably longer than when they remained in the mother tissue. None of the comparatively few embryos treated in this manner developed to a normal state of maturity, however.

IV. Description of the Hybrid Plants

Hybrid plants resulting from *M. albus* × Redfield Yellow crosses were, without exception, strong vigorous plants. In most characters they occupied a position intermediate between the two parents. This was particularly noticeable in the colour of the flowers which were pale yellow or yellowish white in every instance.

Some of the hybrids were completely fertile. They set seed readily and an examination of the pollen revealed mainly normal well filled grains. Others were partially sterile, setting seed only sparingly and producing a high percentage of sterile pollen grains. All of the hybrids produced ample seed, however, from which to grow reasonably large F_2 progenies.

DISCUSSION

Of the sweet clover species crosses, made in these experiments, only those between *M. albus* and Redfield Yellow parents produced hybrids. Not a single hybrid was obtained from over 7000 *M. albus* × *M. officinalis* crosses, although supposed natural hybrids between these species have been described. The latter, however, were not the result of controlled crosses and it may be that the yellow flowered parents of the hybrids reported by Haussknecht, Kirk and Sylven were of the same species as Redfield Yellow, probably *M. suaveolens*.

The intergeneric crosses between *Medicago* and *Melilotus* and between *Medicago* and *Trigonella* were likewise unproductive of hybrids as were also those between *Melilotus* and *Trigonella*. The unusually large number of apparent selfs from the latter cross is interesting. The extent to which apomisis may explain these results has yet to be determined. The consistency with which like results were obtained when the crosses were repeated would indicate that they cannot be explained on the basis of faulty technique.

The production of abortive embryos is significant in that it shows that failure to obtain hybrids was not, in many cases, due to the inability of the pollen to effect fertilization but to the death of the embryo some time after fertilization had taken place. The pods containing abortive embryos ceased development in about 10 days after fertilization. They appeared mature and fell from the plant in from 17 to 21 days, whereas normal pods matured in from 30 to 32 days.

The occurrence of numerous abortive embryos from self-fertilized flowers in many inbred lines of *Melilotus*, more especially in those which possess the non-self-pollinating type of flower structure, as well as in *Trigonella* and *Medicago* to a lesser extent, suggests that the phenomena may be fairly common among legumes. The work of Woodworth (*12*) and Halstead (*3*), on soybeans is of interest in this connection.

The possibility of dissecting out the young hybrid embryos while they are still alive and maturing them on a sterile, nutrient medium is being further investigated. While attempts along this line have not been

successful to date it is interesting to note that the embryos which were removed from the parent tissue and treated thus continued to live and develop much longer than when left on the mother plant.

The hybrids obtained from the *M. albus* × Redfield Yellow crosses, and more particularly those from crosses between the new dwarf branching "Alpha" types and Redfield Yellow, appear to possess many useful agronomic characters. The F_2 dwarf branching type plants are much more vigorous than the parent of the same type and in addition they possess many of the desirable characters of the Redfield Yellow parent.

SUMMARY

1. Interspecific hybrids were readily obtained by crossing *Melilotus albus* with a yellow blossom variety of *Melilotus* known as Redfield Yellow. The hybrid plants were strong and vigorous, most of them perfectly fertile, and a few partially sterile. Marked variations in compatibility between different varieties and individual plants of *M. albus* when crossed with Redfield Yellow were observed. Crosses between varieties of *Melilotus officinalis* and Redfield Yellow produced no viable seed but in some cases shrunken seed with abortive embryos were obtained. It would appear that Redfield Yellow is related genetically more closely to *M. albus* than to *M. officinalis*.

2. No viable seed was obtained from *M. albus* × *M. officinalis* crosses, but in most cases abortive embryos were formed showing that fertilization has taken place. Failure to obtain hybrids from the *Melilotus* species crosses was due to the death of the embryo at an early stage in the development of the seed. The direction in which interspecific crosses were made did not appear to have any influence on the production of abortive embryos.

3. Hybrids were not obtained from any of the following intergeneric crosses: *Medicago media* × *Melilotus albus; Medicago media* × *Melilotus officinalis; Medicago media* × *Trigonella coerulea; Melilotus albus* × *Trigonella coerulea; Melilotus officinalis* × *Trigonella coerulea*. No seed was formed when alfalfa was pollinated by sweet clover but abortive seeds were produced in a few cases from the reciprocals of these crosses. All crosses between sweet clover species or alfalfa and *Trigonella coerulea* were fruitless except in the case of *Trigonella* × *M. albus* when the latter was the female parent. This particular mating produced normal seed greatly in excess of the control flowers which were emasculated but not pollinated. The possibility of apomictic development of the seed is being investigated.

4. Seeds with abortive embryos were produced by self-fertilized flowers of *Melilotus*, *Medicago* and *Trigonella*.

ACKNOWLEDGMENTS

Thanks are due to Dr. W. P. Thompson, Biology Department, University of Saskatchewan, for his kindly interest in this work and for making available the data on the development of abortive embryos. In the work of emasculation and pollination the assistance of Mr. Frank Rose is especially acknowledged.

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Résumé

Etudes de croisements interspécifiques avec le Melilotus et de croisements intergénériques de Melilotus Medicago et de Trigonella. T. M. Stevenson et L. E. Kirk, Laboratoire fédéral des plantes fourragères, Saskatoon, Sask., et Ferme expérimentale centrale, Ottawa, Ont.

On a obtenu facilement des hybrides interspécifiques en croisant *Melilotus albus* avec une variété de *Melilotus* à fleur jaune, connue sous le nom de "Redfield Yellow." Les plants hybrides étaient forts et vigoureux, la plupart d'entre eux tout à fait fertiles, et quelques-uns partiellement stériles. Des variations marquées de compatibilité ont été notées entre les différentes variétés et entre les différentes plantes de *M. albus*, croisées avec le Redfield Yellow. Les croisements effectués entre des variétés de *Melilotus officinalis* et le Redfield Yellow n'ont pas produit de semence viable, mais on a obtenu dans certains cas des semences ratatinées, à embryon abortif. Le Redfield Yellow paraît avoir une parenté génétique plus étroite avec le *M. albus* qu'avec le *M. officinalis*. Les croisements entre *M. albus* et *M. officinalis* n'ont donné aucune semence viable, mais dans la plupart des cas des embryons abortifs se sont formés, montrant qu'il y avait eu fécondation. Si l'on n'a pas réussi à obtenir d'hybrides des croisements effectués entre les espèces de *Melilotus* c'est parce que l'embryon est mort au commencement même du développement de la semence. La direction dans laquelle les croisements interspécifiques ont été faits ne paraît avoir exercé aucun effet sur la production d'embryons abortifs. Aucun hybride n'a été obtenu de l'un ou de l'autre des croisements intergénériques suivants: *Medicago media* x *Melilotus albus; Medicago media* x *Melilotus officinalis; Medicago media* x *Trigonella coerulea; Melilotus albus* x *Trigonella coerulea; Melilotus officinalis* x *Trigonella coerulea.* Aucune graine ne s'est formée lorsque la luzerne était pollinisée par le mélilot, mais les réciproques de ces croisements ont produit, dans quelques cas, des semences abortives. Aucun des croisements entre les espèces de mélilot ou la luzerne et *Trigonella coerulea* n'a donné de produit sauf dans le cas de *Trigonella* x *M. albus* et quand ce dernier était le parent femelle. Ce dernier accouplement a produit de la semence normale en quantité beaucoup plus forte que les fleurs témoins qui avaient été émasculées mais non pollinisées. On étudie actuellement la possibilité du développement apomictique de la semence. Les fleurs auto-fertilisées de *Melilotus*, *Medicago* et *Trigonella* ont produit des semences à embryons abortifs.

BOOK REVIEW

THE GENETICS OF GARDEN PLANTS. M. B. Crane and W. J. C. Lawrence. Toronto: The Macmillan Co. of Canada Ltd. $3.00.

The authors of this book are particularly well qualified for their task of summarizing and presenting in readily understandable form our present knowledge of the genetics of garden and orchard plants. Their joint and several research papers on the genetics and cyto-genetics of horticultural plants are outstanding in that field of work. In addition they know their problems from the point of view of the gardener and the practical grower. The present reviewer being well acquainted with their work expected an outstanding book from them. He is not disappointed.

Considering first the general principles of genetics the authors illustrate their points with well-chosen examples from the crop-plants discussed in detail in the later chapters. The modern viewpoint of the relationship between genes and characters and between the different genes of any genetic complement is summed up in a paragraph which might with great profit be included in every elementary text gook of genetics. "The gene is the unit of reproduction in the hereditary material; and a character the end result of a long and complex chain of reactions which, initiated in the genes, cause the production of the character under favourable environmental conditions . . . . . The fact that a gene (which we may denote by the letter D) causes hairs to form on the fruits of the peach must not be taken to mean that this is the only function of D, or that D independently is able to cause hairs to develop. What it does mean, however, is that the gene D is identified by its most conspicuous effect and that if D is absent the effect will not be produced. Thus peaches breed true to downy skin not merely because they contain the gene D but because their germ-cells contain all the genes necessary for the development of the peach character." And again: "From a genetic point of view it is therefore evident that a plant is a double structure derived from the union of two cells carrying similar or dissimilar genes, the identification of which *depends upon the study of differences.*" (reviewer's italics.)

Unfortunately, though stressing initially this broad interpretation of the nature of the gene, the authors have not gone to the length of modernising the nomenclature of some of the workers whom they quote in the later part of the book. A further criticism might be made of their failure to indicate that the interpretations of mitosis and meiosis which they present are inacceptable in matters of detail to many cytologists. True, they are presenting only an elementary outline of these processes, and they have offered that which is simplest and most concise, but the elements of theory and of generally accepted observation which are involved might have been differentiated.

The chapters presenting the genetics of special crops give in concise form practically all the data available in many cases. The sections on strawberries and pome fruits are particularly good. That on grapes is, however, inadequate. The chapters on incompatibility and sterility, in which the authors have made outstanding original contributions, are very clear presentations of a complex set of problems. The exposition of polyploidy and the discussion of the various means by which new and improved forms of plants originate are well-balanced conservative statements of the extent of our present knowledge. The origin and nature of chimaeras are clearly and concisely explained, and their practical significance is indicated.

Apart from the points cited above and a few minor details of terminology, this book is admirable both as a readily uuderstandable exposition of general genetic principles and as a special reference to the genetics of garden and orchard plants. Undoubtedly it should be read, and kept handy for reference, by every plant breeder and every progressive practical flower, fruit, or vegetable grower or nurseryman.

C. L. HUSKINS.

THE ECONOMIC SITUATION

PREPARED IN THE AGRICULTURAL ECONOMICS BRANCH, DEPARTMENT OF AGRICULTURE, OTTAWA, LARGELY FROM BASIC DATA COLLECTED BY THE DOMINION BUREAU OF STATISTICS

The index number of wholesale prices of 567 commodities advanced from 71.5 in January to 72.0 in February, the highest point reached since June of last year but fractionally lower than in February 1924. Gains were registered in the indexes of vegetable products and animals and their products. The changes in indexes of other sub-groups were not large. Canadian farm products were higher in price, the index rising from 61.4 to 62.0. The index of prices of grain was unchanged at 55.7 but that for animal products rose from 71.0 to 72.6 in February. Retail prices and costs of services were slightly higher, the index being 78.9. Food prices were slightly higher, the index being 69.2 compared with 68.8 in January and 69.3 in December.

Physical Volume of Business.—The index of the physical volume of business reached 100.6 in February. This was the highest point registered in several years and slightly above the index in the base year 1926. It represented a gain of over 3 points compared with that for January. The index of industrial production rose from 97.8 to 101.1, gains in shipments of nickel, copper, silver and gold were fairly substantial. In the manufacturing group, the index advanced from 88.9 to 92.5. Food stuffs contributed the largest gain. A little less activity was shown in the forestry group though output of newsprint and exports of wood and wood pulp and shingles were substantially above the figures for January. A bright spot was the advance in iron and steel production. Automobile production again made a very substantial gain from 73.8 to 104.6. Construction too was somewhat higher than in the month of January, the index rising from 73.4 to 76.9, an increase in building permits being entirely responsible. Trade employment was slightly higher and car loadings were also above the figure for January. Grain and live stock marketings rose from 30.6 to 62.2. Grain marketings advanced from 19.3 to 55.2. Larger shipments of wheat, oats and barley were responsible for the improvement. Live stock marketings rose from 81.5 to 93.4. Very large increases in the marketing of cattle and sheep, a slight increase in shipments of calves and a fairly large increase in hog marketings characterized the movement of live stock during February.

A feature of the live stock situation has been the resumption of trade in cattle with the United States. Up to April 5th, 31,565 head had been shipped across the line compared with 872 in the same period a year ago. Exports to Great Britain have, however, been substantially below those of a year ago. Cold storage holdings were slightly lower than at Januray 1st. Reduced stocks of butter, pork and lard caused the reduction.

Prices in United States.—With the exception of cotton and grain, prices of farm products in the United States have continued to rise. The February index of prices of grain was 114 compared with 115 in January. The index of cotton was unchanged at 108. The index prices of fruit advanced 2 points to 89. In the case of truck crops, the index rose from 117 to 188. That for meat animals advanced from 96 to 105. Dairy products showed a gain of 9 points the index being 121 in February. Chickens and eggs advanced from 114 to 119 and all groups from 107 to 111. The index of prices paid by farmers for commodities bought rose from 126 to 127 and the ratio of prices received to prices paid advanced from 85 to 87. These data are taken from the Agricultural Situation published by the Bureau of Agricultural Economics at Washington.

Prices in Great Britain.—The index of prices of bacon pigs was 120 in February 1935 compared with 129 in February 1934. Pork was 125 and 135 respectively. Dairy cows were 102 and 101. Store cattle 84 compared with 92. Poultry

ANNUAL AND MONTHLY INDEX NUMBERS OF PRICES AND PRODUCTION COMPUTED BY DOMINION BUREAU OF STATISTICS

Year	Wholesale Prices 1926 = 100				Retail prices and cost of services (5)	Production (6) 1926 = 100			
	All commodities (1)	Farm products (2)	Field products (3)	Animal products (4)		Physical volume of business	Industrial production	Agricultural marketings	Cold Storage holdings
1913	64.0	62.6	56.4	77.0	65.4				
1914	65.5	69.2	64.9	79.0	66.0				
1915	70.4	77.7	76.9	79.2	67.3				
1916	84.3	89.7	88.4	92.3	72.5				
1917	114.3	130.0	134.3	119.6	85.6				
1918	127.4	132.9	132.0	134.7	97.4				
1919	134.0	145.5	142.4	152.5	107.2	71.3	65.5	48.1	47.1
1920	155.9	161.6	166.5	149.9	124.2	75.0	69.9	52.6	94.2
1921	110.0	102.8	100.3	108.5	109.2	66.5	60.4	65.2	86.4
1922	97.3	86.7	81.3	99.1	100.0	79.1	76.9	82.6	82.8
1923	98.0	79.8	73.3	95.1	100.0	85.5	83.8	91.4	87.6
1924	99.4	87.0	82.6	97.2	98.0	84.6	82.4	102.5	114.9
1925	102.6	100.4	98.1	105.7	99.3	90.9	89.7	97.2	108.6
1926	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1927	97.7	102.1	99.9	105.7	98.4	106.1	105.6	103.6	110.0
1928	96.4	100.7	92.6	114.3	98.9	117.3	117.8	146.7	112.8
1929	95.6	100.8	93.8	112.5	99.9	125.5	127.4	101.1	109.6
1930	86.6	82.3	70.0	102.9	99.2	109.5	108.0	103.0	128.4
1931	72.2	56.3	43.6	77.6	89.6	93.5	90.4	99.0	125.7
1932	66.7	48.4	41.1	60.7	81.4	78.7	74.0	114.3	120.1
1933	67.1	51.0	45.8	59.6	77.7	79.7	76.8	105.1	115.4
1934	71.6	59.0	53.9	67.6	78.9	94.2	93.6	88.5	114.2
1934									
Jan.	70.6	55.3	47.9	67.8	78.2	86.8	84.5	48.2	108.1
Feb.	72.1	58.0	49.3	72.5	78.7	86.4	84.0	67.1	98.6
Mar.	72.0	56.5	49.5	68.3	79.9	93.1	92.0	63.8	97.0
Apr.	71.1	55.4	48.7	66.6	79.4	92.6	91.4	56.9	94.5
May	71.1	56.9	51.1	66.5	78.5	99.6	99.4	130.6	102.6
June	72.1	59.3	55.5	65.6	78.2	95.8	95.2	97.2	126.1
July	72.0	60.0	57.8	63.7	78.4	95.7	95.6	148.8	116.3
Aug.	72.3	61.6	60.7	63.1	78.7	99.0	99.8	172.8	114.7
Sept.	72.0	61.3	58.9	65.3	79.0	97.1	97.5	127.7	117.7
Oct.	71.4	60.9	55.3	70.4	79.3	95.8	95.3	61.2	128.8
Nov.	71.2	61.2	55.7	70.4	79.4	96.5	97.0	51.2	130.4
Dec.	71.2	61.6	56.0	70.9	79.0	92.4	91.0	36.0	135.7
1935									
Jan.	71.5	61.4	55.7	71.0	78.9	96.5	96.3	30.6	143.7
Feb.	72.0	62.0	55.7	72.6	79.1	100.6	101.1	62.2	141.7

1. See Prices and Price Indexes 1913-1928, pp. 19-21, 270-289 and 1913-1933, p. 15.

2. Wholesale prices of Canadian products of farm origin only. See Prices and Price Indexes 1913-1933, p. 33, and Monthly Mimeographs 1934 and 1935.

3. Wholesale prices of grains, fruits and vegetables.

4. Wholesale prices of Animals and Animal Products.

5. Including foods, rents, fuel, clothing and sundries, See Prices and price Indexes 1913-1928, pp. 181-185, 290-293. 1926=100.

Prices and Price Indexes 1913-1931, p. 108, and Monthly Mimeographs 1934-1935.

6. Monthly Review of Business Statistics, p. 8, and Monthly Indexes of the Physical volume of business in Canada, supplement to the Monthly Review of Business Statistics, November, 1932.

showed a gain of 6 points, the index in February this year being 124. Butter prices were unchanged at 86. Prices of cheese were considerably lower, the index in February 1935 being 94 as against 115. Potatoes were 166 compared with 100 a year ago but had been much higher in November and December with the index at 121 in January of this year. Prices of wool were considerably below those of February 1934. The total index was 115 in February compared with 117 in the previous month.

Farm Land Values.—The value of farm lands in Canada declined to $23 per acre in 1934. During the previous two years it was estimated at $24, whereas in 1929 it was $37, and in 1920 reached the high point of $48 per acre. The values reported by provinces showed that occupied farm lands in New Brunswick have the lowest average value of $24 per acre, whereas in British Columbia land values averaged $60 per acre. It is rather interesting to observe that the values reported in Prince Edward Island were $34 per acre last year compared with $32 per acre in 1933. Similarly, in Nova Scotia farm land was valued at $27 in 1934 compared with $26 in the previous year. Values in New Brunswick were unchanged. In Quebec on the other hand, a decline of $2 per acre was reported, the average in 1934 being given as $34. In the Province of Ontario farm lands increased to $41 compared with $38 in 1933. In Manitoba values were reported to be $1 higher at $17 per acre. There was no change in Alberta and a decline of $3 per acre in British Columbia. Orchard lands in Nova Scotia, Ontario, and British Columbia are reported separately.

LA SITUATION ÉCONOMIQUE

PRÉPARÉ PAR LA DIVISION DE L'ÉCONOMIE AGRICOLE, MINISTÈRE DE L'AGRICULTURE, OTTAWA, PRINCIPALEMENT D'APRÈS LES DONNÉES RECUEILLIES PAR LE BUREAU FÉDÉRAL DE LA STATISTIQUE

Le chiffre indice des prix de gros de 567 produits, après avoir atteint 71.5 en janvier, est monté à 72.0 en février; c'est le plus haut point qu'il ait atteint depuis juin l'année dernière, mais il est encore d'une fraction plus bas qu'en février 1934. Des augmentations ont été enregistrées dans les indices des produits végétaux et des animaux et leurs produits. Les changements notés dans les indices d'autres sous-groupes ne sont pas considérables. Les prix des produits de la ferme canadiens ont monté, l'indice passant de 61.4 à 62.0. L'indice des prix du grain est resté au même point, à 55.7, mais celui des produits animaux s'est élevé de 71.0 à 72.6 en février. Les prix du détail et les frais des services étaient un peu plus élevés, l'indice atteignant 78.9. Les prix des denrées alimentaires étaient aussi un peu plus élevés, l'indice étant de 69.2 contre 68.8 en janvier et 69.3 en décembre.

Volume physique des affaires.—L'indice du volume physique des affaires a atteint 100.6 en février, c'est le plus haut point qui ait été enregistré depuis plusieurs années; il est légèrement supérieur à l'indice de l'année de base 1926. Il représentait un gain de plus de 3 points sur celui de janvier. L'indice de la production industrielle s'est élevé de 97.8 à 101.1, les augmentations notées dans les expéditions de nickel, de cuivre, d'argent et d'or étaient assez considérables. Dans le groupe des produits manufacturés, l'indice est passé de 88.9 à 92.5. Ce sont les produits alimentaires qui ont fourni la plus forte augmentation. Le groupe forestier manifestait un peu moins d'activité, quoique la production de papier à journal et les exportations de bois de pulpe et de bardeaux fussent bien supérieures au chiffre de janvier. Un trait réjouissant est la hausse enregistrée dans la production du fer et de l'acier; la production des automobiles a encore enregistré une très forte augmentation, passant de 73.8 à 104.6. L'industrie du bâtiment était aussi à un niveau un peu plus élevé qu'en janvier, l'indice passant de 73.4 à 76.9; cette amélioration est due entièrement à une augmentation dans le nombre de permis de construction. Le nombre d'employés dans le commerce était un peu plus élevé et les chargements de wagons étaient également supérieurs au chiffre de janvier. Les ventes de grain et de bestiaux ont passé de 30.6 à 62.2. L'augmentation pour les ventes de grain seules a été de 19.3 à 55.2 en raison des expéditions plus fortes de blé, d'avoine et d'orge. Les ventes de bestiaux ont passé de 81.5 à 93.4. Le commerce des bestiaux en février s'est signalé par de très fortes augmentations dans les ventes de bovins adultes et de moutons, une légère augmentation dans les expéditions de veaux et une assez forte augmentation dans les ventes de porcs.

Un trait spécialement à signaler dans la situation du bétail est la reprise du commerce des bovins avec les Etats-Unis. Jusqu'au 5 avril il s'était expédié 31,565 animaux de l'autre côté de la frontière contre 872 pendant la même période l'année dernière. Quant aux exportations en Grande-Bretagne elles ont été bien inférieures à celles d'il y a un an. Les stocks de produits en entrepôt étaient un peu inférieurs à ceux du 1er janvier. Cette réduction portait principalement sur le beurre, le lard et le saindoux.

Prix aux Etats-Unis.—A l'exception du coton et du grain, les prix des produits de la ferme aux Etats-Unis ont continué à augmenter. L'indice du prix du grain en février était de 114 contre 115 en janvier. L'indice du coton est resté au même point à 108. L'indice des prix des fruits est monté de 2 points, à 89. En ce qui concerne les récoltes maraîchères, l'indice a passé de 117 à 188, celui des animaux à viande de 96 à 105. Les produits laitiers accusaient un gain de 9 points, l'indice étant de 121 en février. Les poulets et les œufs ont passé de 114 à 119 et tous les

groupes de 107 à 111. L'indice des prix payés par les cultivateurs pour les marchandises achetées est monté de 126 à 127 et la relation entre les prix reçus et les prix payés s'est élevée de 85 à 87. Ces données sont extraites de la "Situation agricole" publiée par le Bureau de l'économie agricole à Washington.

Prix en Grande-Bretagne.—L'indice des prix des porcs à bacon était à 120 en février 1935 contre 129 en février 1934. Le porc était à 125 et 135 respectivement. Les vaches laitières étaient à 102 et 101. Les bœufs d'engrais à 84 contre 92. Les volailles accusaient un gain de 6 points, l'indice de février cette année étant de 124. Les prix du beurre sont restés au même point, à 86. Les prix du fromage étaient beaucoup plus bas, l'indice de février 1935 étant de 94 contre 115. Les pommes de terre étaient à 166 contre 100 l'année dernière, mais elles avaient été beaucoup plus élevées en novembre et en décembre, l'indice était à 121 en janvier de cette année. Les prix de la laine étaient bien inférieurs à ceux de février 1934. L'indice total était à 115 en février contre 117 en janvier.

Valeur des terres arables.—La valeur des terres arables au Canada était de $23 par acre en 1934. Pendant les deux années précédentes, elle avait été estimée à $24, tandis qu'en 1929 elle était à $37, et én 1920 elle avait atteint le chiffre élevé de $48 par acre. Les valeurs signalées par les provinces montrent que les terres arables occupées au Nouveau-Brunswick sont celles qui ont la plus faible valeur moyenne, savoir, $24 par acre, tandis qu'en Colombie-Britannique cette valeur était en moyenne de $60 par acre. Un fait intéressant à noter c'est que la valeur enregistrée dans l'Ile du Prince-Edouard était de $34 par acre l'année dernière contre $32 par acre en 1933. De même, en Nouvelle-Ecosse, la terre arable était évaluée à $27 en 1934 contre $26 l'année précédente. Au Nouveau-Brunswick, il n'y a pas eu de changement dans la valeur. Par contre, dans le Québec, on signale une diminution de $2 par acre, la moyenne en 1934 était de $34. Dans la province de l'Ontario, la valeur des terres arables est montée à $41 contre $38 en 1933. Au Manitoba elle a remonté de $1, soit $17 par acre. Il n'y a pas eu de changement dans l'Alberta tandis que l'on enregistrait une baisse de $3 par acre en Colombie-Britannique. Les terres en vergers dans la Nouvelle-Ecosse, l'Ontario et la Colombie-Britannique sont l'objet d'un rapport séparé.